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Construction project administration and management for mitigating work zone crashes and fatalities: An integrated risk management model

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Construction project administration and management for mitigating work zone crashes and fatalities: An integrated risk management model

by

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ABSTRACT

Each year in the United States hundreds of people die in automobile crashes in highway work zones and tens of thousands of motorists suffer injury or property damage due to crashes in highway work zones. The traveling public, designers, department of transportation agencies, and contractors will all benefit from research aimed at the reduction of crashes in highway work zones. Although much past research has delved into the various causes of work zone crashes and the various strategies to mitigate work zone crashes, little effort has been given to the overall management of the risks associated with work zone crashes. The goal of this research is to develop a new, integrated approach to the management of these risks. This goal is achieved through the development of a formal integrated risk management model to be utilized during the construction management and administration of highway projects for all stages of the project lifecycle. Within this integrated risk management program, validation and application of the model is accomplished by focusing on the three components of the standard risk management model: risk identification, risk analysis, and risk response. This project requires a multi-faceted research approach employing several methodologies. With the exception of the risk assessment portion of this research, the methodology for this project is primarily qualitative, using focus groups, surveys, personal interviews, and content analysis to identify work zone risks, mitigating strategies and the proper stakeholders and project phases in which to implement mitigating strategies. The model validation phase of this research involves qualitative assessments along with an analytic assessment of work zone hazards through database queries into a statewide crash database to produce a risk matrix tool. The risk matrix tool is a two dimensional representation of the frequency and severity of crashes with specific characteristics (hazards) that are associated with the crash and can be used by a risk management team to prioritize their responses to work zone risk.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Each year in the United States over 900 people die in automobile crashes in highway work zones (Iowa DOT, 2008a). In addition, 40,000 motorists involved in crashes in highway work zones suffer from injuries and 52,000 are involved in property damage only crashes (Mohan, 2002). It is in the interest of the traveling public, designers, department of transportation agencies, and contractors to explore methods to reduce these tragic statistics. The goal of this research is to develop a new, integrated approach to risk mitigation of highway crashes and fatalities in transportation construction work zones. This goal is primarily achieved through the development of a formal integrated risk management model to be utilized during the construction management and administration of highway projects for all stages of the project lifecycle, from planning through construction. Within the integrated risk management program, validation and application of the model is accomplished by focusing on the three components of the standard risk management model: risk identification, risk analysis, and risk response (Smith, 1999). The risks are generally identified by recognizing the factors that contribute to work zone crashes. The analysis of risk deals with understanding of the probability of a hazard influencing the frequency or severity of a loss, and the risk response relates to the deployment of appropriate counter-measures to attenuate the factors that contribute to work zone crashes. The number of hazards and mitigation strategies can be substantial.

This research project develops a check list for the project management team and establishes scenario-based questions that will accompany risk management brainstorming sessions. These scenario-based questions are derived from established proximate causes (loss of control, loss of visibility, and confusion) to identify potential hazards on the plans, designs, or jobsite. The scenario-based questions used to cue the risk response that deals with mitigation strategies may take the form of a mitigation "method" (alert motorist, assist worker/motorist, control motorist, inform motorist, and protect worker/motorist). The results of this research will be an integrated, risk mitigation model defining a formal step-by-step process to be utilized by managers and decision makers. At each stage of the project lifecycle (or project development process), the model suggests a checklist of hazards and mitigation strategies to be considered. After development of the integrated risk model, the research validates the identification, analysis, and response components through a quasi-quantitative method to assess the likelihood and severity that a hazard or multiple hazards could pose on a roadway work zone.

Aside from offering practical strategies for use by contractors and designers, this dissertation offers academic contributions as well. This dissertation creates a tool for the comprehensive quasi-quantitative analysis of risks using actual crash data supplied by the Iowa Department of Transportation. It identifies possible avenues and ideas for future innovation in risk management in highway work zones and fills gaps in the existing literature on the subject. Existing research has been conducted for the most part in such a way as to identify crash factors affecting work zones in terms of a one dimensional approach at the most severe level (fatal). This dissertation will take a multi dimensional approach through the examination of work zone hazards through the application of a risk model incorporating multiple severity levels (fatal, injury and property damage only) and the corresponding frequencies.

1.2 BACKGROUND

On average there are 900 fatalities per year in roadway work zones in the United States (Iowa DOT, 2008a). In Iowa, there are an average of 6.5 deaths per year, 136 injury crashes, and 224 property damage only crashes, for an average total of 366 total work zone crashes per year. Ninety percent of Iowa work zone fatalities are motorists (Iowa DOT, 2008a). Past research has addressed the primary factors that contribute to work zone crashes involving injuries or fatalities and the mitigation strategies has been focused on physical measures taken during construction. Some of the identified factors have been shown to include: speed, inattentive driving, following distance, aggressive driving, and large trucks (Iowa DOT, 1999; Dissanayake, 2002; Chambless, 2002; Roadway Safety Foundation, 2007; Hausman, 2007). The leading types or causes of work zone accidents are: rear-end collisions, workers struck by motorists, workers struck by construction equipment (mostly when backing up), and motorist collisions with large trucks (Garber, 2002; Hausman, 2007; Pratt, 2001; Pigman, 1990). In addition, the times in which work-zone accidents are most likely to occur have been determined: night time (dark), Fridays, evenings of weekends (after bar time), summer months, and in periods of heavier traffic (Hausman, 2007; Pigman, 1990; Pratt, 2001).

Typical initiatives to reduce the number of fatalities and injuries are usually physical in nature (i.e. barricades, signage) and are put in place in the actual work zone during construction (Pratt, 2001; Richard, 1986; Hargroves, 1981; Bushman, 2005). However, physical traffic calming measures have not always proven to be effective when not followed up by enforcement (Arnold, 2003; Pratt, 2001; Richard, 1986; Huebshman, 2003). Therefore it may prove more effective and efficient to use innovative contracting and project administration to address work zone safety in the planning, design and preconstruction phases of the project.

1.3 PROBLEM STATEMENT

Work zone accidents can be classified according to: (1) accidents that occur in the work zone that are caused by and affect only the parties in the contract (construction workers, Department of Transportation (DOT) personnel, consultants, etc.), and (2) accidents that occur because of the interaction between the traveling public and participants in the construction process. Therefore, two groups of parties are generally impacted by work zone accidents: the project workers on site, and the traveling public. Workers are affected by both the jobsite conditions and the effect of interactions with passing motorists. The traveling public is also affected by jobsite conditions and other construction related conditions, as well as other travelers in the work zone. This research focuses on the interaction of the traveling public, the worker, and work zone conditions (merging patterns, signage, construction equipment, truck traffic, barricades, lighting, speed, congestions, etc.). Much research has been undertaken in the past that will prove valuable in identifying mitigation strategies and providing additional resources to reduce the number of injuries and fatalities in work zones. However, the focus of this research is to develop and implement an accident mitigation program to manage the existing strategies in order to provide the greatest benefit to the traveling public, the contractor, and transportation agencies.

Taken strictly from a need basis, all parties involved in the construction project can benefit from the implementation of an accident mitigation program. This program will take the form of a formal risk management program that will specifically address the needs at the construction project administration and management level. The benefits to developing a formal risk management model are vast; however, the following is an abbreviated list of some motivations for developing an integrated risk management program:

- save lives;
- decrease injuries;
- reduce property damage;
- moderate risk of liability;
- lower insurance premiums for contractors;
- reduce costs associated with claims/litigation;
- decrease project delays;
- reduce traffic delays (social/economic);
- curtail knee-jerk reactions (overcompensation); and
- provide proper allocation of resources based on likelihood and cost of risk.

Some of the additional potential benefits to developing and implementing an accident mitigation program at the construction project administration and management level will likely come in the form of improvements to innovation and technology as it relates to work zone safety.

There are several topics which are beyond the scope of this research project. Jobsite accidents that are not directly related to the interaction with the traveling public will not be included in this research. These are the types of jobsite-related accidents that may occur whether or not the work is conducted in the vicinity of the traveling public. Some examples include: workers on foot struck by construction vehicles or equipment, falls, equipment roll-overs or collisions, etc. In essence, any jobsite safety concern that would typically be addressed by company safety policy and Occupational Safety and Health Administration (OSHA) regulations will not be included in this research. However, developing a mitigation program for jobsite safety will be recommended for future research. Therefore, from this point forward, this dissertation will concentrate on the mitigation of work zone "crashes" as the term "crash" infers an interaction with the traveling public, the worker, and the work zone conditions.

1.3.1 Current Standard of Practice

Examination of the current state of practice within the industry, as exemplified by the Iowa DOT, indicates the primary utilization of the Manual on Uniform Traffic Control Devices (MUTCD) at the design level. The general concept is that a project is designed as needed based on project requirements, whereupon the methods section of the Iowa DOT develops a Traffic Control Plan (TCP) based on input gathered from a variety of sources such as the Regional Planning Affiliation (RPA), Metropolitan Planning Organization (MPO), Transportation Improvement Program (TIP), and the Iowa County Engineers Association Service Bureau (ICEASB). In general, the TCP's follow closely to the specifications of the MUTCD. The traffic control plans are presented in the project plans along with any anticipated traffic events (civic and social events and holidays). By following established standards, the current state of practice appears to take an approach of mitigation of liability as opposed to mitigation of traffic crashes and fatalities. This approach operates under the assumption that if a plan is created and followed according to professional standards, there is less chance of a lawsuit being filed, even if the plan is inadequate. However, if a plan was created but not followed, even if the implemented measures are better than the plan, the likelihood of a lawsuit is increased. The philosophy behind the use of standardized traffic control plans generated from a group of standards detailed in the MUTCD is that standardization minimizes confusion for the traveling public. The accepted belief is that when unique traffic control measures or designs are implemented, drivers are more likely to become confused. Therefore, it is the intent of this research to develop a program that delves deeper into work zone conditions and traffic control by analyzing the factors that contribute to work zone crashes and fatalities. These factors will further be categorized into components in order to provide structure to the program.

1.3.2 Key Components to Accident Mitigation

Just as roadway safety can be categorized by the four E's of highway safety (Education, Engineering, Enforcement and Emergency Response), this research posits that work zone crash mitigation may also be categorized by the source (component) of the crash mitigation strategy. Past research has addressed the many factors related to accident prevention (Bai, 2008; Pratt, 2001; Garber, 1990, Beacher, 2005; Pain, 1983, Bushman, 2005); however there is a lack of research that specifically addresses accident mitigation in terms of components as related to responsibilities of stakeholders within the construction process. In past research, general measures to prevent accidents and injuries in work zones have been suggested and compiled into lists of recommended practices or possible future innovations. The purpose of this research differs from past research in that it develops the research methodology for accident (crash) mitigation by defining the key components of accident mitigation, thereby developing a procedure or process to determine which party or parties is best suited to manage the mitigation strategies of each component. Five components emerge among the lists of mitigation strategies:

1) Education
2) Enforcement/Legislation
3) Design/Planning
4) Scheduling/Contracting
5) Construction Operations.

The following is a brief outline showing some of the sub-items of each of the proposed components.

- Education:
  - Information
    - General Information
    - Work Zone Awareness Initiatives
    - Lane Closures
    - Alternate Routes
    - Media Outlets
  - Training
    - Driver Training
    - Worker safety training
    - Flagger Training
  - Signage
    - Chevrons
    - Information Boards

- Late Lane Merges

- Enforcement/Legislation:
  - Speed Control
  - Traffic Control
  - Vandalism Prevention (sign theft, etc.)
  - Surveillance
  - Driver Assistance (break downs, etc.)
  - Fines (double in work zones) & litigation
  - Accident Investigation (future prevention)

- Design/Planning:
  - MUTCD vs. Innovation
  - Traffic Control Plans
  - Coordination between stockholders
  - Identify constraints and opportunities
    - Highways for life programs requirements
    - Business owner requirements
    - Project particulars & critical elements

- Scheduling/Contracting:
  - Jobsite congestion/activities
  - Anticipated traffic densities (date/season/workday)
  - Construction schedule
  - Bid Items for safety training
  - Bid Items for driver assistance
  - Bid Items for Monitoring/Surveillance
  - Bid Items for construction vehicle spotters and ground guides

- Construction Operations:
  - Flagging
  - Barricading
  - Re-Route traffic
  - Internal Traffic Control Plans (Contractor)
  - Monitoring/Surveillance – off hours
  - Construction Traffic/Congestion
  - Driver Assistance Programs (by contractor)
  - Accident Investigation (future accidents or liability)
  - “Near Miss” reporting procedures (future accidents)

1.4 RESEARCH OBJECTIVES

This research explores mitigating work zone fatalities and accidents through construction project administration and management. The objective of such mitigation strategies is to address work zone safety risks before construction starts. Essentially a "Loss Control Program" (Dorfman, 2005) may be implemented in the form of a risk management model. Considering the five components of crash mitigation discussed in the previous section it is apparent that the party that is in a position to best manage the risk may or may not be part of the construction phase of the project. The party that can best manage the risk may be a stakeholder in any of the stages of the construction project life cycle (i.e., planning and programming, design, letting, and construction). The objective of this research is to explore strategies for mitigating work zone fatalities and accidents before construction starts through project administration and management. Therefore, this research will create a formal risk management model to be utilized during the construction management and administration of highway projects in order to mitigate work zone accidents and fatalities for all stages of the project life cycle.

This dissertation emphasizes the mitigation of transportation work zone crashes and fatalities; however, this project has been developed in such a way that the model presented can serve as a framework or template for managing risks pertaining to all types of construction projects. This research is intended to provide a holistic approach to risk management that is to be integrated into the existing corporate structure and not to be considered a stand alone program. This integrated approach will allow a formalized procedure to be utilized by any member of an organization during all phases of the project life cycle. Risk management is one of the many functional requirements for the project management and administration of construction projects (Fisk, 2006). This research develops a formalized process to manage risks during all phases of the project lifecycle; therefore, the framework was created using best practices from all industries that utilize risk management functions. This allows managers to utilize this framework for all risks that are associated with construction projects regardless of the risk classification. While useful in all areas of construction, the risk management process formalized in this research will be examined through in-depth focus on the creation of a formal risk management process that is unique to highway construction projects focusing on the life safety issue of mitigating work zone crashes and fatalities.

Using the framework and the step by step process developed in this project will allow project managers and administrators to integrate this model into their existing management structure, allowing stakeholders to manage multiple risks within the project regardless of risk classification (i.e., social risks, political, life safety, economic, scheduling). The purpose of this framework is to implement a risk management strategy as early as possible in the project life cycle in order to better manage that risk through effective decision making and identification of stakeholders that are best suited to manage those risks.

The standard risk management model (identify, assess, respond) includes four responses to risk; (1) accept, (2) transfer, (3) avoid, or (4) reduce (mitigate). The primary risk associated with work zones as applied to this research is vehicle crashes in the vicinity of the project site as defined by the limits of work zone area. The appropriate response to the risk of a work zone crash is to reduce or mitigate either the frequency or severity of such crashes since work zone crashes cannot be completely avoided, cannot be responsibly accepted, and are extremely difficult to transfer to another party. Risk mitigation strategies are created by determining the contributing factors (hazards) of work zone crashes, assessing the risks associated with the factors, and responding to the risk by implementing appropriate counter-measures (work zone management strategies) to the contributing factors. Ultimately, this research will be used to:

- determine when and how to use various work zone management strategies;
- effectively identify and quantify risks; and
- mitigate risks utilizing the existing known strategies.

This research will not intentionally be used as a means to establish new strategies but is meant to stimulate innovation and promote the use of technology in response to the efforts of the risk management program. The end result of this research is the creation of a loss control program in the form of an integrated risk management model. This integrated risk management program will provide a formal step by step process that will be used to identify, assess, and respond to risks by providing check lists and brainstorming cues that will assist the risk management team across all stages of the project lifecycle of any highway construction project.

1.5 PREVIEW OF DISSERTATION

This dissertation starts out with an introduction, problem statement and research objectives in Chapter 1. Chapter 2 provides a detailed literature review. The primary purposes of the literature review are for the definition of key concepts and the review of past research in managing work zone risks for the intention of establishing the point of departure for this project. This research utilizes the terminology associated with management and administration of construction projects, risk, risk management, and stages of the construction project life cycle. Since there is some variation in definitions of terms used in the construction industry, it is the intent of Chapter 2 to provide a baseline understanding of the construction terminology associated with this project. The research methodology is provided in Chapter 3. This describes the research approach and expands in detail the general method of the research and the specific tasks performed in this portion of the research. The risk management model for this research is developed in Chapter 4. The model was developed using a number of "best practices" from numerous industries and sources. This section develops the framework for the integrated risk management model, and goes into detail to describe the standard risk management model as it pertains to each stage of the project life cycle. Chapter 5 discusses the validation and application of the model as developed in Chapter 4. This is accomplished by addressing the identification, assessment and mitigation strategies for work zone hazards for each phase or stage of the project life cycle. Chapter 6 provides conclusions and recommendations of the research. It also provides recommendations for future research; discusses limitations of this research; and provides a generalized concept of the use of the integrated risk management model in related construction realms.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The policies and actions of the project management and administrators associated with a highway project will have a great effect on the safety outcomes of the project. This research focuses on the project management and administrative functions involved in transportation projects. Therefore, this research utilizes the literature review as a method to define the process by which transportation design and construction projects are managed. The approach of this chapter is to create a baseline for the understanding of the terms required to fully create and implement a formal risk management program for all stages of the project lifecycle by project managers and project administrators followed by a review of past research in the area of risk management in projects involving work zone safety in order to establish the point of departure for this project. Although this dissertation is primarily concerned with the mitigation of work zone accidents and fatalities, it was the goal of the research to keep the format of risk management in general terms in order for agencies and individuals to use the proposed risk management model to manage multiple project risks. Therefore, the literature review is utilized to create a risk management model by defining concepts in terms that apply to the design and construction industry as a whole and not exclusively to highway projects. The validation and application of the model presented in this dissertation is based exclusively on input from highway sector professionals and highway crash data and is therefore applicable specifically to that industry. Once the framework has been developed for an integrated risk management program, the desired risk category may be explored within the existing risk management structure. This will allow researchers and practitioners to focus on the standard risk management model without recreating the structure needed to integrate the risk management model into an existing management structure.

The integrated risk management model can be understood by considering the research target shown in Figure 2.1.1. The outer ring of the target shows project management and administration which represents the overall existing corporate structure. The framework of the management and administration functions spans the entire project life cycle. Thus, the project phases represent the next inner circle of the research target. The project life cycle is defined in the research target in order to acknowledge required tasks and subsequently, the risks that can be identified within those activities. In addition, each stage or phase of the project life cycle includes stakeholders that may or may not be unique to that particular project stage. Parties that are best suited to manage the risks within a particular phase should be part of the risk management team. The next circle on the research target is the integrated risk management program. This research program serves as the framework for a formal step-by-step process that will assist the risk management team with the implementation of the program with the purpose to ensure continuity and a standard approach to risk management within a corporate structure. This will allow stakeholders at all levels of management to follow the same procedures that may improve the level of objectivity provided by the risk management approach. The integrated risk management program encompasses the elements of the existing standard risk management model as shown in Figure 2.1.1 and focuses on identification, assessment, and response to various risks. Note that the outer circles of the research target may be applied to any project related risks during any phase of the project lifecycle; however the innermost circle or bulls-eye represents a specific risk classification. For this dissertation, the "bulls-eye" is the risk of work zone crashes on roadways.

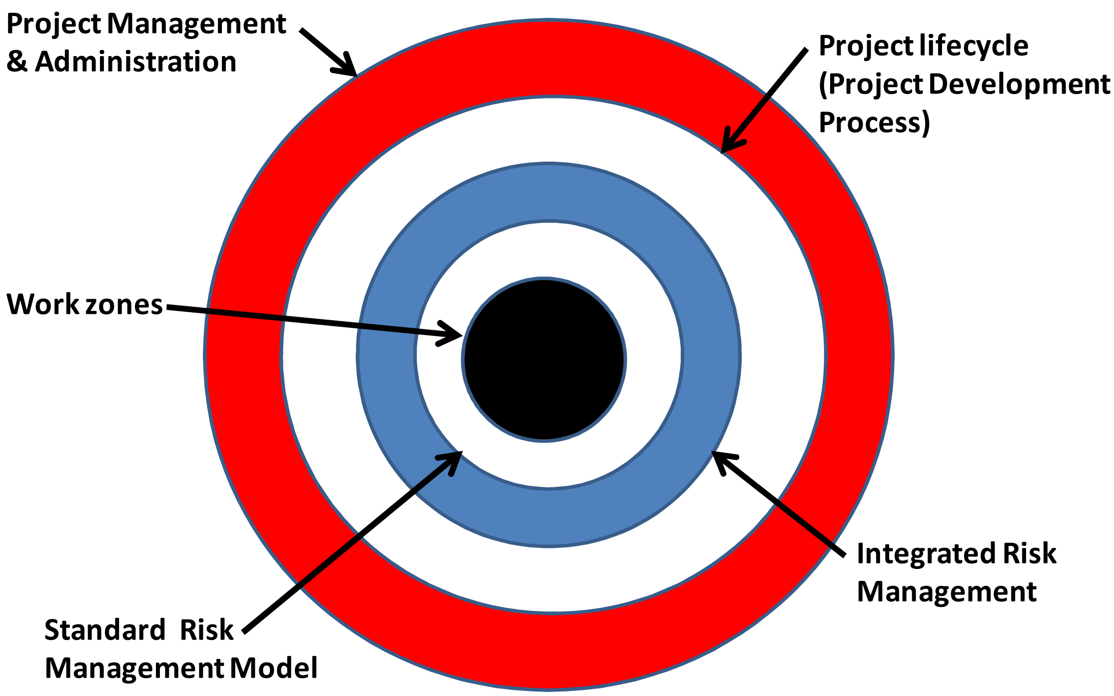


Figure 2.1.1 Research Target - Integrated Risk Management Model for Highway Work zone Projects

The remainder of this chapter and Chapter four will be focused on developing the outer rings of the research target. However, in order to provide an in-depth analysis into the use of the risk management model, it will be applied to address the specific risks associated with the mitigation of work zones crashes and fatalities.

The concepts explored in this literature review focus on the following areas, starting with a global perspective and narrowing to the specific topic of this research:

- project management and administration;
- the project life cycle;
- project development process (highway construction); and
- risk / risk management.

The literature review lays the framework from which the integrated risk management model was created. The review takes several individual aspects of project management and administration and distills them into a comprehensive system to be utilized for a specific purpose of accident mitigation of roadway work zones.

2.2 CONSTRUCTION PROJECT MANAGEMENT AND ADMINISTRATION

2.2.1 Management versus Administration:

Defining **management** and **administration** in terms of their function in a construction project ensures that the appropriate associated risk management tasks can be determined and ultimately that the appropriate personnel and/or stakeholders can be assigned to each task. Since there are multiple stakeholders associated with the administration and management of a construction project and since there is some disagreement within the industry as to the definition of **management** and **administration**, defining the terms accurately in line with industry standards is essential in order that all stakeholders have a common point of reference from which to make recommendations or observations.

2.2.2 General Industry Definitions of Management and Administration

According to E.F.L Brech, one of Britain's leading authorities on management, "management is neither a science nor an art. It is the overall process of executive jurisdiction for planning, motivating and control…and administration is that part of the management process concerned with the institution and carrying out of the procedures by which the program is laid down and communicated, and the progress of activities are regulated and checked against targets and plans" (Brech 1969). Alternatively, Oliver Sheldon defines management as "the function concerned in the execution of policy within the limits set up by administration and the employment of the organization for the particular objects before it, whilst administration is the function concerned in the determination of corporate policy" (Information Science Today, 2008).

In order to determine which definition is most applicable to the construction industry, several key words were compiled for each term as found from a multiple of sources. In discussion relating to the key concepts associated with public administration versus public management, key words associated with administration include: ministering (attend to the wants and needs of others), justice (pursue lawfully), duty (moral obligation) and practicality. In contrast the key words associated with management include: results, efficiency, objectivity and science (Stivers, 2003)). Fredrick Taylor and Henry Gantt popularized the idea of scientific management in the early 20th Century and came to the conclusion that "scientific management is the application of principles and methodology of modern science to problems of administration" (Information Science Today, 2008). According to Stuhlman Management Consultants, "management is the organizational process that includes strategic planning, setting objectives, managing resources, deploying the human and financial assets needed to achieve objectives and measuring results. Management also includes recording and storing facts and information for later use or for others within the organization" (Stuhlman, 2008).

Succinctly, management can be defined as encompassing all functions related to creating policy. In contrast administration is defined as encompassing all functions that relate to following policy.

2.2.3 Construction Industry Definitions

Delineating the differences between the functions of management and administration throughout the construction process is essential in the identification of the specific associated tasks in each of the phases of the project life cycle. A central distinction between project management and project administration can be made by examining the phases in which the responsibilities of each are invoked. In particular, project management responsibilities span the entire life-cycle of the project, whereas, specific administrative functions span only certain phases of the project, such as contract administration responsibilities (Kavanagh, 1978).

The construction phase is divided into two main categories: construction contract administration and construction project management. The Construction Specifications Institute (CSI) – Manual of Practice (2005) defines construction project management activities as those relating to managing the construction process and are typically performed by the contractor. A partial list of those activities include: performing the work of the project in accordance with the contract documents, project coordination, compliance with quality provisions, submittal procedures, execution of work, contract closeout procedure, and compliance with warranty provisions. Specific methodologies and component programs which are associated with construction management include: systems analysis, the systems approach, systems engineering, systems building, comprehensive planning, operations research, value analysis, cost engineering, life-cycle costs, cost-benefit analysis, technology assessment, network analysis, simulation (modeling), phased construction, scheduling, expediting, monitoring/control and other procedures involved with the application of scientific management and scientific method (Kavanagh, 1978).

The CSI Manual of Practice (2005) also defines the activities of the construction contract administration as those relating to the administering of the contract for construction. Typical activities performed by the construction contract administrator include: reviewing submittals, providing construction evaluation services, evaluating proposals for contract modifications, certifying applications for payment, and making final inspections of work for contract closeout (CSI, 2005). Differentiating between the oft interchanged terms, construction administration and contract administration, Fisk (2006) defines contract administration as the management or handling of the business relations between parties of a contract—administrative paperwork and electronic project management applications. Fisk (2006) refers to construction administration as a much broader responsibility relating to all project-related functions between parties to a contract in much the same way as CSI (2005) defines construction administration, but with greater detail. In addition to the traditional contract administration duties, Fisk (2006) suggests that construction administration includes the following duties: conduct of the parties, relations with contractor, communications, business systems, procedures, responsibility, authority and duties of all the parties, documentation requirements, construction operations, planning and scheduling, coordination, materials control, payment administration, change orders and extra work, dispute and claim handling, negotiations, and all project closeout functions (including punch list inspections), final cleanup, and administrative closeout. As such, contract administration is merely a part of construction administration (Fisk, 2006).

2.2.4 Midwest Transportation Consortium (MTC) Research Definitions

For the purposes of research related to risk management in construction work zones, project management extends across all phases of the project life cycle. Therefore, the basic responsibilities and tasks of the project management team will encompass all areas of each of the phases of the project life cycle. Project management then refers to the tasks and responsibilities required for project coordination and integration, and not necessarily to the specific personnel or individuals performing the tasks. The purpose of identifying the project management tasks and responsibilities is to provide a baseline for which the panel experts (focus group) will identify stakeholders and from which to specifically document the current state of the practice of risk management in each phase of the project life cycle.

During the construction phase, the construction project management and construction project administration is delineated by the managerial and administrative tasks and responsibilities as well as the individuals performing the function. During the construction phase, the construction project manager is considered to represent the contractor on the project, while the construction project administrator represents the owner.

Table 2.2.1-- Construction Project Management and Administration Task List

Construction Project Management and Administration Task List	
Project Management Tasks (Kavanagh, 1978)	Project Administration Tasks (Fisk, 2006)
• systems analysis • the systems approach • systems engineering • systems building • comprehensive planning • operations research • value analysis • cost engineering • life-cycle costs • cost-benefit analysis • technology assessment • network analysis • simulation (modeling) • phased construction • scheduling • expediting • monitoring/control • the application of scientific management and scientific method	• conduct of the parties • relations with contractor • communications • business systems • procedures • responsibility • authority and duties of all the parties • documentation requirements • construction operations • planning and scheduling • coordination, materials control • payment administration • change orders and extra work • dispute and claim handling • negotiations • project closeout functions (including punch list inspections) • final cleanup • administrative closeout
Project Management Tasks (CSI, 2005)	Project Administration Tasks (CSI, 2005)
• performing the work in accordance with the contract documents • project coordination • compliance with quality provisions • submittal procedures • execution of work • contract closeout procedure (punch list) • compliance with warranty provisions	• reviewing submittals • providing construction evaluation services • evaluating proposals for contract modifications • certifying applicants for payment • making final inspections of work for contract closeout

Each is responsible for the contract compliance by its respective party to the contract (CSI, 2005). For this research, the term construction project administrator refers to all aspects of construction administration as it applies to the parties of the contract. The specific tasks of the construction project administrator are as described by (Fisk, 2006) and are summarized in Table 2.2.1.

2.3 PROJECT LIFE CYCLE (STAGES OF CONSTRUCTION PROJECTS)

2.3.1 Project Phases

The phases of a construction projects have been described somewhat differently according to different authors. In the following sections, an overall view of project phases will be explored from the perspective of a typical construction project. Following this discussion, the processes will be adapted specifically to transportation projects. The similarities between the project lifecycle terminology used in a typical non-highway project will be compared and contrasted with the terminology typical to a transportation project. Bennett (1985) describes the execution of a construction project according to two phases—the strategic phase and the tactical phases. During the strategic phase of construction, the end product and the organizational factors required to meet the end product are determined. According to Bennett (1985), this phase is primarily concerned with problem solving. During the strategic phase, the client's objectives, the model of the end product, and a model of the project organization are brought into balance, resulting in the definition of specific roles.

During the tactical phase of construction the project organization focuses on team selection, motivation techniques, and team performance feedback (Bennett, 1985). Kavanagh (1978) identifies three stages of construction projects: pre-design, design and construction. The pre-design sequence includes concept planning, budgeting, funding, feasibility studies, programming, and site selection. The design stage is completed in three phases or stages: schematic or sketch design phase (conceptual design phase); design development (preliminary design); design documents (working drawings). Finally, the construction stage involves implementation of the project definition. Further, CSI (2005) expands the definition of the construction project life cycle to include six distinct phases: project conception; design (schematic design and design development); construction documentation (final design); bidding and negotiating; construction; and facility management. The following sections will provide a detailed description of each of the six project phases as defined by CSI. For this dissertation the CSI definition of the project life cycle was adopted as a framework to springboard the focus group discussion. However, the project development process (PDP) for highway projects, as described in later sections, served as the framework for this research.

2.3.2 Project Conception

The project conception phase initiates the construction project and is the first phase in the construction project life cycle. The project conception phase includes the following major activities: concept planning, programming, feasibility studies, budgeting, site analysis and site selection. Concept planning is the activity that determines the needs and objectives of the project. During this activity existing conditions, future requirements, urgency of project, and schedule are integrated in order to provide the input required for the programming activities. The programming activities focus on the functional and architectural requirements of the project. The functional programming activity determines the purpose, defines the scope, and develops the required function of the construction project, while the architectural programming activity is primarily concerned with meeting the aesthetic needs and developing the design solutions.

The feasibility studies evaluate the practicality of the proposed project. As the project takes definitive form, feasibility and/or economic studies of the project and its proposed results should be conducted (Kavanagh, 1978). This is accomplished through the use of preliminary studies, relevant information, and statistical projections (CSI, 2005). Feasibility studies test the various aspects of an owner's vision. If the vision is not financially viable, it must be substantially modified or abandoned (CSI, 2005).

The budgeting activities determine estimated costs of the project and develop a budget and contingencies associated with the project (Kavanagh, 1978). The project budget should include projections of all of the costs associated with the entire project. A project budget may consider initial construction cost exclusively, or may include projected costs of operation. Including the operations and maintenance costs in a project budget will provide a better understanding of the total life cycle costs (CSI, 2005).

Site analysis includes activities which are used to determine the environmental, social, and cultural applicability of the proposed site to the project parameters. Site studies are a key activity of the project conception stage. A site study evaluates the likelihood that a particular location will be able to support the facility throughout its life cycle (CSI, 2005).

The site selection is a comparison of possible sites that provide a definitive opportunity for the application of value analysis (Kavanagh, 1978). Time and money are also factors in the site selection and acquisition. If a site does not immediately meet the requirements of the project, addressing the problems and limitations may be costly and time consuming (CSI, 2005).

2.3.3 Design

Schematic design (also considered the conceptual design) defines the concept, evaluates materials to be utilized, and establishes systems and outlines specifications for the project. The schematic design converts program requirements into an architectural solutions which best suit the site (Kavanagh, 1978). Written documents usually consist of preliminary project descriptions and preliminary cost projections. Schematic design phase drawings may include sketches, renderings, or conceptual diagrams. These drawings describe the size, shape, volume, spatial relationships, and functional characteristics of project components. They are usually general in nature, with few dimensions (CSI, 2005). Following the schematic design phase, the design development (preliminary design) activities formalize the adopted scheme and convert it into basic plans for all major components of the facilities. As a rule of thumb, the design development phase includes approximately 25% of the total design (Kavanagh, 1978). The emphasis shifts from overall relationships and functions to more technical issues of constructability and integration of systems and components. During the design development phase, more detailed information is required. Drawings in this phase may show multiple views of the project in order to describe materials and basic systems and their interrelationships. Changes to the project or its major systems can be made at this time with relative ease compared to later in the design/construction process (CSI, 2005).

2.3.4 Construction Documentation

The construction documentation (final design) activities formalize all aspects and detail all aspects of the facility. The functional, architectural and specific owner requirements are documented and translated into plans and specifications (Kavanagh, 1978). Major changes made later during design or after construction has begun can have a significant impact on the total cost and schedule of the project. The contract documents describe the proposed construction (referred to as the *work*) that results from performing services, furnishing labor, and supplying and incorporating materials and equipment into the construction. Contract documents consist of both written and graphic elements and typically include the following: contracting requirements; specifications; and contract drawings. The contractor, through signing an agreement with the owner, agrees to the responsibility of accomplishing the work in accordance with the contract documents (CSI, 2005).

2.3.5 Bidding/Negotiating/Purchasing

The transition from the design stage to the construction stage of a project is the bidding/negotiating/purchasing stage collectively known as *procurement.* During this stage, owners make the proposed construction documents available to prospective contractors, through either direct selection or open solicitation. The prospective contractors assemble, calculate, and formally present to the owner their prices to complete the project described in the procurement documents. Construction prices become the financial basis of the contract for construction (CSI, 2005).

2.3.6 Construction

Construction is the execution of the work as required by the contract documents. Construction is the coordinated effort of all those involved in providing the owner with a successful project. The construction stage includes the contractor's planning and scheduling activities, mobilization of equipment, material purchasing, fabrication of components, and construction. Primary decision makers during this stage for a typical construction project are the architect/engineer (A/E) or design consultant owner, and contractor. Construction activities can be divided into two broad categories: Construction contract administration and contractor project management (CSI, 2005).

2.3.7 Facility Management

Facility management is the process of allocating resources for the operation and maintenance of a facility to allow continued performance of the facility's intended function. The facility manager is involved in project closeout to assist in the successful transfer of the completed facility for the owner's use. Prior to substantial completion of construction, most construction contracts require that the contractor prepare a *punch list* for the project. The punch list identifies incomplete work and items requiring correction. Substantial completion of construction is the point at which the project is sufficiently complete for the owner to occupy or utilize the facility for its intended use. The date of substantial completion is established by the A/E and documented by the issuance of a certificate of substantial completion. The commissioning agent helps ensure that the facility performs in accordance with the contract documents.

Table 2.3.2—Typical Project Stages (From Figure 1.5-B Typical Project Stages (The Project Resource Manual – CSI Manual of Practice, 2005)

STAGES	ACTIVITIES	Owner Documents	A/E Documents	Contractor Documents
PROJECT CONCEPTION	Feasibility Study Programming Site Analysis Site Selection	➢ Program ➢ Budget ➢ Schedule	➢ Reports ➢ Analysis ➢ Recommendations	
DESIGN	Schematic Design	➢ Surveys ➢ Geotechnical Data	➢ Schematic Drawings • Sketches • Renderings • Diagrams ➢ Conceptual • Plans • Elevations • Sections ➢ Preliminary Project Description ➢ Cost Projections	
	Design Development		➢ Drawings • Plans • Elevations • Sections • Typical Details ➢ Engineering • Design Criteria • Equipment Layouts ➢ Outline Specifications ➢ Revised Cost Projections	
CONSTRUCTION DOCUMENTATION	Construction Documents (or Final Design)	➢ Solicitation ➢ Instructions for Procurement ➢ Bid/Proposal Form ➢ General Conditions ➢ Supplementary Conditions	➢ Detailed Drawings • Plans • Elevations • Sections • Details • Schedules ➢ Specifications ➢ Bidding Requirements ➢ Revised Cost Projections	

STAGES	ACTIVITIES	Owner Documents	A/E Documents	Contractor Documents
BIDDING/ NEGOTIATING/ PURCHASING	Competitive Bidding or Contract Negotiations Direct Purchasing of Goods and Supplies	Request for Proposal Purchase Orders	Addenda	Bid Bid Security
CONSTRUCTION	Mobilization Construction Contract Administratio n Project Closeout	Payment Certificates	Modifications	Permits Schedules Shop Drawings Certificates Record Documents Warranties Operation and Maintenance Data
FACILITY MANAGEMENT	Occupancy Operation/Ma intenance Evaluation Repairs	Maintenance Records	Pre-Occupancy Reports or Analysis	Warranty Service Records

2.4 PROJECT LIFE CYCLE AS DEFINED BY STATE HIGHWAY AGENCIES

Building on the basic process discussed above, a review of the application of such a process specific to transportation projects will be explored. A review of numerous literatures support the proposition that in general there are there are few differences between the **processes** of horizontal (highway) and vertical (building) construction project life cycles (Bennett, 1985; CSI, 2005; Kavanagh, 1978; Anderson, 2004). The primary differences come in the terminology used to describe each stage of the construction project life cycle and the descriptions of the process itself. The variability in the definition of the stages of the construction project life cycles between highway (horizontal) projects as described by state highway agencies and non-highway (vertical) construction projects and the diversity of sources writing on the subject, necessitates the selection of a project life cycle definition which is both conducive to generalization and concise. While there are many published forms of the project life cycle, the CSI (2005) definition of the project provides the most applicable explanation of the process regardless of the type of project (Figure 2.4.1). This dissertation relies heavily on the CSI definitions in order to provide more clarity to the project development process (PDP) as defined by state highway agencies.

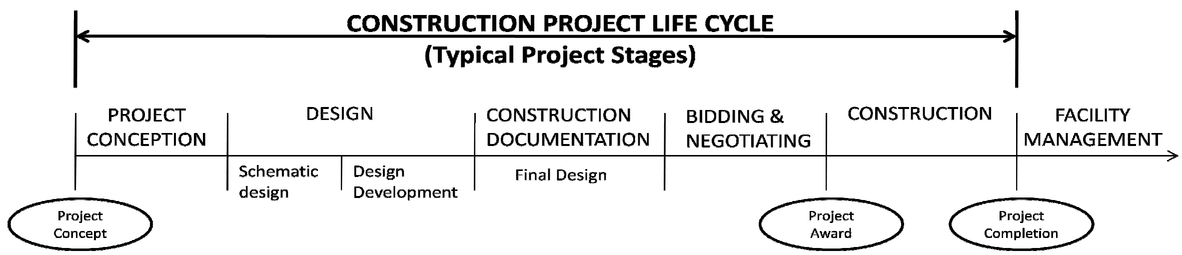


Figure 2.4.1 Construction Project Life Cycle – Construction Specifications Institute (CSI)

Regardless of the type of project constructed, the first stage is the concept planning. State highway agencies refer to this stage as *planning and programming*. Regardless of the term (planning, conceptual design, etc.) the basic activities of this stage are:

- determining needs and objectives;
- identifying alternative projects that will meet the needs and objectives while providing a viable return on investment;
- determining the appropriate location for the project;
- performing various studies (to include feasibility);

- estimating the cost based on the conceptual design;
- identifying funding sources; and
- programming the project by ensuring that the functional and engineering capabilities of the project meet the needs and objective outlined in the initial planning stages.

Once it has been determined that a project is viable, it is authorized to move to the next phase—design. Although CSI (2005) defines this first stage as *project conception* the activities associated with this stage are identical to the activities associated with *planning and programming* as described by stage highway agencies.

According to CSI (2005), there are essentially three phases to the design stage-preliminary design, detailed design (design development) and final design. The Iowa DOT uses the terms preliminary plans, check plans, and final plans. Again, although the terms are different, the process is similar. The preliminary design consists of general “stick” drawings that define the concept and shows the spatial relationship of the components of the project. These include general alignment and layouts. For highway projects this also starts the data collection process for rights-of-way and utilities, and environmental assessment. Some state highway agencies refer to this process as *preliminary line and grade*. An environmental clearance is required in order to transition from preliminary design to design development; therefore, the preliminary design stage is separated from the design development phase. This is in contrast with the CSI (2005) documents that include preliminary design and design development in the same stage. For most state highway agencies, once environmental concurrence has been obtained, the project proceeds to detailed design or the *final design* stage. For the state highway agencies, the final design stage can be referred to by several different terms such as PS&E (planning, specifications and estimates) development, *check plans* and *final plans*. During the design development phase, the adopted theme is formalized, and systems and components are integrated (traffic control, roadway/pavement/bridge/drainage design, permitting, constructability). Depending on the approval process, the final corrections to the detailed “check” plans are translated into the final PS &E documents (final plans). For state highway agencies this stage also includes the negotiation and acquisition of rights of way (ROW’s). The general concept of this stage aligns closely to the *construction documentation* stage described by CSI (2005)—with the exception that the design development (detailed design) is typically considered part of the design process by state highway agencies. Upon completion of the final design stage, the project proceeds to the letting stage.

During the letting stage, construction documents are made available to prospective contractors, prospective contractors prepare a price in the form of a bid, and the bid is reviewed, a contractor is selected and a contract is signed. This stage is called the *bidding/negotiating/purchasing (procurement)* phase by CSI (2005); however the process is identical to the “letting” process that is typically adopted by state highway agencies.

The construction stage of the project life cycle as defined by various state highway agencies also has similarities to CSI (2005). This stage includes: planning and scheduling, mobilization, purchasing, contract administration, construction management, inspections, construction and traffic control. This phase also includes project closeout functions, although some of these closeout functions would be included in the facility management phase of the project lifecycle as described by CSI (2005).

The following section of this dissertation describes in more detail the process in which a "typical" state highway agency develops a typical highway related project.

2.5 PROJECT DEVELOPMENT PROCESS (HIGHWAY CONSTRUCTION)

The Construction Project Life Cycle is a generic process which describes the activities associated with the planning, design, procurement and construction of specific constructed facility. The intent of this section is to specifically identify the stages of a construction project life cycle as it applies to the planning, design, and construction of highway and roadway projects. However, as with the description of the "generic" construction project life cycles, where many organizations (such as Construction Specifications Institute (CSI) or Design Build Institute of America (DBIA)) and authors use differing terminology to describe the project phases, also the state highway agencies vary in their descriptions from state to state. The Iowa DOT defines this process as the Project Delivery Process (PDP). The term *project development* is "a series of processes (e.g., planning, programming, design, and construction) that convert highway transportation needs into a completed facility that satisfies the need" (Anderson, 2004). The Federal Highway Administration (FHWA) describes the project delivery process in two phases: planning and project development (Contract Administration, 2001). The planning process focuses on planning and programming. Long range plans are based on transportation needs and short term plans are focused on specific projects.

National Cooperative Highway Research Program (NCHRP) Synthesis 331states that one of the goals of the state highway agencies (SHA's) is to maintain, upgrade and improve the highway systems within the state (Anderson, 2004). NCHRP Synthesis 331 further states that SHA's must identify and prioritize transportation needs and then address the needs with the implementation of individual projects (Anderson, 2004). Therefore, lists of needs and potential projects are created. The cost associated with the proposed project is required to effectively translate the need into a viable project. When a funding agreement (by various entities) has been executed, the project is "programmed" and authorized for further development (Iowa DOT, 2008c). According to NCHRP 331, authorized projects move through advanced planning and preliminary design, including environmental clearance, to the final design. When the ROW is acquired, the project goes through the letting phase. The project is awarded (if it meets the bidding requirements) and the construction process begins.

In the absence of documentation which fully describes the activities involved in each stage of the Iowa DOT's specific project delivery method in the application of federal aid to roadway projects, interviews with DOT personnel and an adaptation of a modified version of the PDP as described by Anderson (2004) is used to describe the stages of the project development process. Anderson (2004) terms these phases as: planning, programming advanced planning/preliminary design, final design, letting, award, and construction. Since the Iowa DOT describes "programming" as an event that authorizes the project to proceed to the following stages (Iowa DOT, 2008c), this project modifies the PDP of Anderson (2004) as follows: the initial stage of the PDP for this research combines *planning and programming*. The second stage of the PDP is the *preliminary design*. The third stage is *final* *design*. The fourth stage combines *letting & award*, and the final stage of the PDP is *construction*. Figure 2.5.1 graphically displays these stages of the PDP.

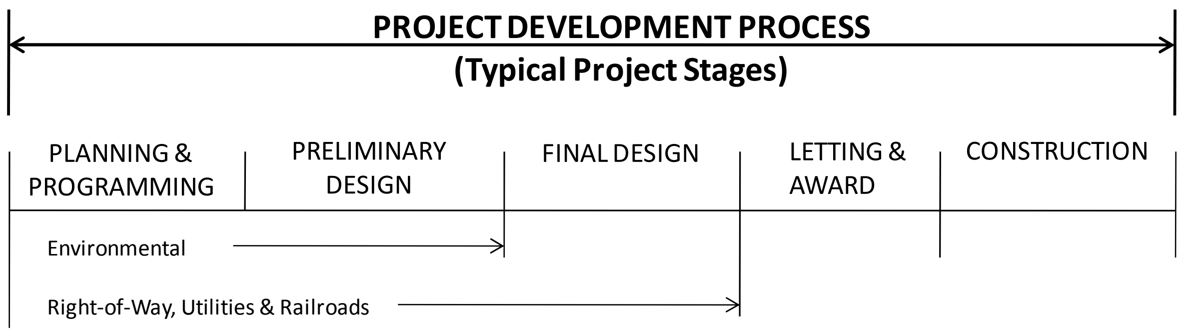


Figure 2.5.1 Typical Stages of the Project Development Process (PDP)

The remainder of this section is allocated to expanding on the specific activities to be performed by state highway agencies during each of the previously defined stages of the project development process. The understanding of each of these stages is critical in determining the activities that have the greatest impact on identifying hazards and mitigating accidents and fatalities in work zones. The intent of the following sections it to generically identify the activities associated with each phase with respect to the construction of transportation facilities.

2.5.1 Planning and Programming

Planning activities are essential in determining the need and the scope of a proposed project. The Iowa DOT (2007a) describes transit planning as a process to determine the community's current and future needs for public transportation and to choose the best match between those needs and the available resources (Iowa DOT, 2007a). The need for a project may be identified in many ways, including suggestions from maintenance supervisors, area engineers, district staff, local elected officials, developers, and the traveling public. Once a project is suggested, research should be conducted to prioritize the need for one project relative to others competing for limited funds (TxDOT, 2008). Once needs have been identified, a design team compiles a range of alternatives that meet the purpose and need. The subject matter expert (SME) will need to consider a corridor approach to a given alignment so that adjustments can be made to avoid or minimize impacts. Key decisions ensure that the environmental and design processes are integrated, and that the different entities are consulted to provide the necessary input to the project team (Hancher, 2003). Typical planning activities include: purpose and need, improvement or requirement studies, environmental considerations, and interagency coordination (Anderson, 2004). During the planning phase the types of studies which may be involved include: Feasibility study, Route study, Toll road study, Corridor study, Subarea study, Major Investment study (MIS)/environmental documentation, and value engineering study.

The Iowa DOT (2008c) defines programming as a "general term to refer to a series of activities carried out by planners, including data assessment, appraisal of identified planning needs, and consideration of available or anticipated fiscal resources to result in the drawing up, scheduling, and planning of a list of identified transportation improvements for a given period of time" (Iowa DOT, 2008c). The programming and scheduling process for transportation projects involves a number of steps, including identifying transportation needs, selecting and prioritizing projects, authorizing and scheduling project development, and funding and implementing the work (TxDOT, 2001). Typical programming activities include: environmental determination, schematic development, public hearings, right of way (ROW) plan, and project funding authorization (Anderson, 2004).

2.5.2 Preliminary Design

The Iowa DOT (2007b) defines the activities associated with the preliminary design of a project: "this task begins with the preparation of the plans and ends with submittal of the plans to the Iowa DOT Administering Office. It includes all work required to produce a set of preliminary plans, including, as applicable: survey and mapping , preliminary design, plan and profile layouts, identification of preliminary right-of-way needs, internal reviews by the consultant, and reviews by the Local Planning Authority (LPA)" (Iowa DOT, 2007b). The preliminary plans are used by the Iowa DOT to evaluate the proposed project design, right-of-way needs, and possible environmental impacts (Iowa DOT, 2008b). For the purpose of this research, the preliminary design stage will include: data collection, ROW development, environmental clearance, design criteria and parameters, surveys/utility locations/drainage, preliminary schematics such as alternative selections, geometric alignments, bridge layouts and value engineering (Anderson, 2004, TxDOT, 2008).

2.5.3 Final Design

Once an environmental concurrence has been established, the PDP progresses into the final design stage. This task begins with review of the Iowa DOT comments on the preliminary plans, progresses through the submittal and review of check plans, and ends with the preparation and review of the final plans (Iowa DOT, 2007b). This stage includes all work required to address the preliminary plan comments and produce a complete set of check plans; including, as applicable: final design (pavement and bridge design, traffic control plans, utility drawings, hydraulic studies/drainage design), establishment of final ROW needs (ROW acquisition), calculation of bid quantities, preparation of cost estimates, Special Provisions, and reviews (Anderson, 2004, TxDOT, 2008).

2.5.4 Letting & Award

This task begins when final plans and associated information are submitted for letting to the Office of Contracts and ends when the bids are opened and the apparent low-bidder is announced. The Iowa DOT letting process includes the following activities, as applicable: preparation of cost estimates, establishment of contract periods, preparation of bid proposals, Disadvantage Business Enterprise (DBE) goal setting, Federal Highway Administration (FHWA) Authorization, distribution of addenda, advertisement, and opening of bids. This task also includes additional review of the project plans and specifications for conformance to the Iowa DOT Standard Specifications and letting process (Iowa DOT, 2007b). The letting processes entails the preparation of contract documents, advertisement for bids, pre-bid conferences, and the receiving and analysis of bids, while the award process involves the determination of the lowest responsive bidder and the initiation of the contract (Anderson, 2004).

2.5.5 Construction

The Iowa DOT (2008b) explains the responsibilities associated with the construction phase: "unless specified otherwise in the funding agreement, the LPA (Local Planning

Authority) will be responsible for all aspects of administration and inspection of the construction contract. This includes providing daily, on-site inspection of the contractor's work activities and processing all of the paper work associated with the construction contract, including any change orders" (Iowa DOT, 2008b). This stage includes: mobilization, inspection and materials testing, contract administration, and traffic control, bridge, pavement, and drainage construction (Anderson, 2004).

2.6 INTEGRATED RISK MANAGEMENT

Referring back to Figure 2.1.1, the research target—integrated risk management model for highway work zone projects, integrated risk management falls under the confines of the project lifecycle (or project development process as described in the previous sections) which in turn falls under the confines of the project management and administration function. Refer to Figure 2.6.1 for a snapshot of the evolutionary process of risk identification through the development of a risk management program. The remainder of this chapter will be dedicated to the definition of the terms required in order to build such a program.

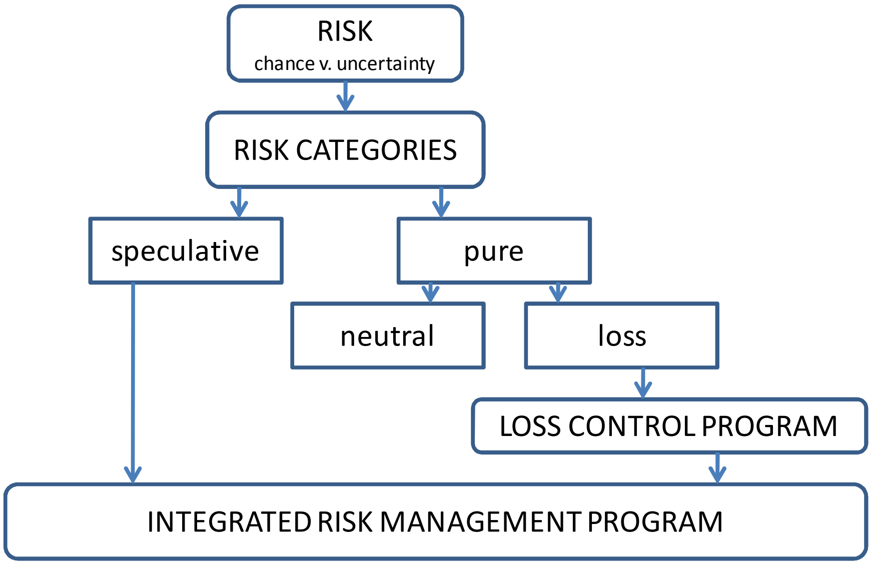


Figure 2.6.1 – Flow chart of risk related topics

The following sections are arranged in order to provide a logical flow from the understanding of project risk to the development of an integrated risk management program. This section provides the basic level of knowledge and understanding that is necessary to create a program that is specifically suited to the construction industry for any type of construction project. Figure 2.6.1 displays a graphical representation of the layout of the following sections. The discussion will start with the definition of risk and will flow through the definition of loss; it will describe the process of loss control, and ultimately end the discussion with the definition of an integrated risk management program.

2.6.1 Risk

The study of risk and risk management has been dominated by the insurance and finance industry. However, the terms and definitions used by the insurance and finance industries are applicable to the construction industry as well. Fisk (2006) and Smith (1999) have been on the forefront in writing about risk as it applies to the construction industry. Just as with the definitions for management and phases of the project lifecycle, there are as many definitions of risk as there are authors that write about risk. Related terminology which has been used in similar applications as “risk”, include “probability”, “chance”, and “uncertainty.” According to Fisk (2006), risk is defined as the “variations in possible outcomes that exist in nature in a given situation.” He goes on to clarify that “this definition of risk is to distinguish between risk and probability. Risk describes an entire probability distribution, whereas there is a separate probability for each outcome” (Fisk, 2006). Risk exists when a decision is expressed in terms of a range of possible outcomes and when known probabilities can be attached to the outcomes (Smith 1999). Dorfman (2005) defines risk as the variation of possible outcomes of an event based on chance. That is, the greater the number of different outcomes that may occur the greater the risk. The greater the variation around an average expected loss, the greater the risk (Dorfman, 2005). Therefore, the understanding of risk revolves around a known probability for a specific outcome. This concept has been traced to 1738 when Daniel Bernoulli published an article on risk aversion in the market place (Moss, 2002). Although Bernoulli was referring to economic risk he essentially showed that expected value was derived from a known probability.

According to these authors, risk is related to a known probability. Unfortunately, there are many instances where the probability of an outcome is unknown. And since the probability is unknown there is uncertainty in the outcome. “Uncertainty is a measure of ignorance” (Berstein, 1996). Uncertainty exists when there is more than one possible outcome of a course of action but the probability of each outcome is not known. Smith (1999) explains: “this means that uncertainty relates to the occurrence of an event about which little is known except that it may occur. Those who distinguish uncertainty from risk define a risk as being where the outcome of an event, or each set of possible outcomes, can be predicted on the basis of statistical probability. This understanding of risk implies that there is some knowledge about a risk, as opposed to an uncertainty about which there is no knowledge.” Risk can be defined in terms of statistics and uncertainty. Dorfman (2005) notes that although the variability of outcomes emphasizes the statistical aspect of risk and insurance, the uncertainty concept emphasizes the behavioral aspect of the people exposed to risk. Dorfman (2005) goes on to define risk as the variability in possible outcomes where events are based on chance or uncertainty, where uncertainty refers to the concern of a possible loss.

Therefore this research accepts the definition of risk as it relates to chance and uncertainty. For this dissertation chance refers to the outcome based on a known probability, whereas, uncertainty refers to the outcome of an unknown probability. This definition works well within the confines of this research. Fortunately for the traveling public, the law of large numbers—the idea that a larger data set will lead to greater predictability power—does not apply to work zone crashes and fatalities. The limited crash data available can be utilized to assess the probability of some of the risks associated with roadway work zones, however, many of the work zone risks will have a degree of uncertainty.

2.6.2 Categories of Risk

In terms of insurability, there are two types of risk: pure risk and speculative risk. Pure risk is a risk that results in only a loss or no change. Essentially, “nothing good comes from pure risk” (Dorfman, 2005). Crockford (1986) defines pure risk as a risk that is undesirable. Speculative risk, on the other hand, refers to the exposure that could result in gain or loss. Most investments are viewed as speculative risk (Dorfman, 2005). Speculative risks are risks that have the possibility of advantage. This definition recognizes that all risks are not threats and that all risks are not necessarily to be avoided (Crockford, 1986). Although there are other categories and classification of risks, pure risk and speculative risk are the categories most applicable to this research and other classifications have been intentionally omitted in order to simplify this discussion.

2.6.3 Loss

Understanding loss is essential to the development of a program to prevent or control losses. Since the bulk of this research involves the risks associated with highway work zone crashes, it is necessary to delve deeper into the effects of pure risks as it refers to losses. Loss is an undesired and unplanned loss of economic value (Dorfman, 2005). The chance of loss occurring is equal to the number of losses divided by the number of exposures to the loss. The insurance industry defines “peril” as the cause of a loss and a “hazard” is defined as a circumstance that either increases the frequency or severity of losses (Dorfman, 2005).

It is terms in this section that are critical in risk charting that will be discussed in subsequent sections. For this reason, this section discusses loss particularly as it is seen from the perspective of the insurance industry. “In their consideration of risk, insurance people concentrate on consequences. They tend to think of risk in terms such as material damage risks, personal accident risks, liability risks, interruption risks etc., thus classifying them according to the effect produced. Classification of this kind is, however, of limited use in seeking to identify threats if the aim is to prevent them from producing the consequences” (Crockford, 1986). The goal of this research is to investigate risk in the same manner as the actuary. Therefore, this section will define terms associated with that of the insurance industry. It is understood that in many cases of law and insurance, losses are analyzed after the fact. It is one of the goals of this research to utilize the method of causation to determine the factors associated with events that could potentially lead to losses. The following is a list of definitions as they pertain to losses:

> **Direct Loss –** Immediate reduction in economic value (i.e.: If a building burns the direct loss is the value of the building itself (Denneberg, 1964)).
>
> **Indirect Loss –** Loss as a consequence as a secondary effect of a direct loss (i.e. Consequential or indirect losses would include the value of the lost income during the business interruption and the extra expense incurred to continue business elsewhere (Denneberg, 1964)).

Damage is probably the most immediately apparent threat to a company’s material property, just as the interruption that may result is the chief threat to earnings (Crockford, 1986).

Table 2.6.1— Sources of Loss (from Dennenberg (1964) – Sources of Loss)

LOSS CLASSIFICATION	EXAMPLE
Personal	Premature death, accident, sickness, unemployment, superannuation
Property	Damaged, destroyed, wrongfully taken by others
Liability	Legal judgment

In order to manage losses, it is necessary to identify the process in which a loss occurs. In the process of risk identification this concept is called “risk charting” – which will be covered in subsequent sections of this chapter. Ultimately an exposte view of the situation that causes loss shows a sequential order of events which lead to the loss:

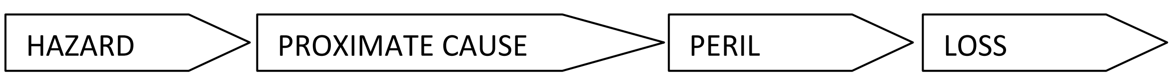


Figure 2.6.2 Graphical representation of causation between hazard and loss

Hazard- a circumstance that either increases the frequency or severity of losses (bad character, weather conditions, faulty equipment)

Proximate Cause - the initial act which sets off a sequence of events that produce losses (a legal term that implies negligence)

Peril – the cause of a loss (fire, automobile crash, hurricane, etc.)

Loss - undesired, unplanned loss of economic value (delay, property damage, disability, death)

While a hazard is described as something that increases the likelihood of a loss (Heimer, 1985), hazards can be further classified into physical hazards, moral hazards, and morale hazards. Physical hazards arise from the natural condition of property or from impersonal surroundings (Denneberg, 1964). This category of hazards can include everything from a badly wired house to living in a hurricane zone (Heimer, 1985). Legal hazards can be a subset of physical hazards which are laws, contracts and legal interpretations that modify the likelihood of loss from a covered peril. Moral hazards are conditions that are not precisely physical hazards but nevertheless increase the odds of loss. Insurers sometimes attribute moral hazard to bad character: "those conditions that increase the frequency or severity of loss because of the attitude and character of an insured person" (Denneberg, 1964). Moral hazards can also include a tendency toward fraud, a departure from the standards of conduct acceptable to society, carelessness, poor housekeeping or absentmindedness. Generally a moral hazard, as referenced by the insurance industry, is a character trait that exists prior to insurance coverage (Heimer 1985). Another hazard category is termed morale hazard and is defined as a decline in vigilance (loss-prevention activity) which contributes to increased accident-proneness or carelessness. This is likely a change in incentives that occurs after coverage (Heimer, 1985).

Table 2.6.2—Hazard Examples (from Heimer, 1985)

HAZARD CATEGORY	**EXAMPLE**
Physical Hazard	Worn brake shoes, slippery road
Moral Hazard	Inebriation or history of alcoholism, lack of respect for traffic rules
Morale hazard	Discontinue long established habit of locking car door after buying theft insurance

The Dictionary of International Insurance & Financial Terms (2001) defines proximate cause as "the immediate effective cause of an insured loss." The idea of proximate cause stems from a legal sense exposte of the peril that caused a loss to occur. However, the purpose for explaining the concept of proximate cause is to show that there is a cause-and-effect relationship between hazard, peril, and loss. Although, proximate cause assumes a degree of negligence, the concept of an initial act that sets off a string of events that leads to loss is especially useful in risk mapping and ultimately risk management when the concept is taken as exante'. This relationship will form the basis for the risk management approach of this research. In legal terms, to be liable for negligence, not only must the defendant fall below a standard of reasonable conduct and consequently violate a duty to the plaintiff, but his negligence must be the proximate cause of the injury. This means that the negligence must in fact cause the injury and that a sufficiently close connection between the negligence and the injury will persuade a court to affix responsibility upon the defendant. This latter element is called "proximate" or "legal cause" (Denneberg, 1964). The negligence must have been the cause without which the accident would not have happened (Vaughan, 2001). This proximate cause can also be defined as a chain of causation (Williams, 1985). The peril then, is the actual cause of the loss.

This can all be tied together through an illustration by Dorfman (2005):

A stored container of gasoline in a building is a hazard to the premises. A discarded cigarette is the proximate cause for the ignition of the gasoline. A fire is the peril. And property damage to the house is the loss.

The idea here is that in order for a loss to occur, a hazard must be present, and action must be applied to a situation that causes something to happen that results in a loss. This will become the central theme of the risk management and loss prevention approach that will follow this section and will re-emerge throughout this research.

2.6.4 Loss Control

Although the ultimate goal of this research is to develop a risk management model or approach to be utilized by the construction industry, an intermediate goal is to develop the model in the area of pure risk management. This is accomplished by delving into the subject of loss control. Again, much can be drawn from the body of research which the insurance industry has produced in terms of loss control. Loss control programs which involve the management of pure risks can be expanded to use as a basis for the development of a risk management program to deal with all risks (pure and speculative). The following section will discuss the essential elements of loss control in terms of loss reduction and loss prevention. Since the topic of this research project emphasizes the mitigation of work zone crashes and fatalities, it is understood that life safety is of paramount importance. As shown in the previous section, personal loss is the result of pure risk that has been realized. This section will define the process of loss control that will serve as the basis for developing the full risk management model.

Loss control measures are used to manage risks by lowering the chance that a loss will occur or by reducing the severity if it does occur. This is accomplished by the development of loss reduction and loss prevention programs. Loss prevention programs attempt to reduce or eliminate the chance of a loss whereas loss reduction programs attempt to reduce the potential severity of a loss (Williams, 1985). Central to any effective risk management program is effective loss control. Efficient and economically feasible systems to minimize losses reduce the fluctuation in loss records and ensure that risk financing decisions are taken on the basis of sufficiently reliable data (Crockford, 1986).

Loss Prevention activities lower the frequency of losses. As long as the benefits exceed the costs, loss prevention should be used to treat all exposure, however, without exception, the foremost purpose of loss prevention is to preserve human life. A risk manager's first goal in a loss prevention program is to reduce or eliminate the chance of death or injury to people (Dorfman, 2005). Subsequent chapters of this work will discuss in detail various mitigating strategies that include loss prevention. An abbreviated list of some of the strategies employed in roadway work zones include: barriers, traffic control devices, education, training, law enforcement, signage, and driver information.

Loss Reduction activities reduce loss severity by way of preventing the loss from spreading or getting worse (Dorfman, 2005). For this research topic some examples of risk reduction activities would include: flagging, driver awareness initiatives, emergency response, and driver assistance programs. The concept of loss reduction will be discussed in detail in later chapters of this work which will do into detail in a discussion of various mitigating strategies for the reduction of work zone crashes.

Responsibility of Loss Control starts at the top of an organization. The ultimate and major responsibility for loss control is within the firm itself. Within an individual firm, the responsibility is shared by all of its divisions in varying degrees (Williams, 1985). Some organizations outsource loss prevention through the employment of "specialists", however many experts claim that an effective loss control program should involve every member of an organization (Crockford, 1986). Crockford (1986) summarizes that "the problems of coordinating loss control within an organization are very similar to those of coordinating risk management as a whole. If it is not seen as everyone's task, and if it is left to the specialist to worry about, then he alone will have to carry the immense burden of trying to bring about, in the face of indifference or opposition from all around him, something that can only be achieved through cooperation" (Crockford, 1986).

Loss and Hazard Analysis Awareness is the key factor to loss control. Everyone connected with the organization must be made aware that losses are possible and that they can be controlled (Crockford, 1986).This can be accomplished by identifying and analyzing losses that have occurred and hazards that have caused losses or could cause future losses. This process requires diligent book-keeping and routine inspections (Williams, 1985). In order for this process to work, selected individuals are required to provide information about accidents and a standardized form to report accidents is required. Information provided must list all accidents and "near misses" regardless of severity. Just as with losses and potential losses, hazards need to be analyzed in the same way by identifying hazards that have caused accidents or could cause accidents. The understanding of loss and hazard analysis is also of great importance to this research as check lists and assessment tools have been created in order to assist risk managers with loss control functions associated with the traveling public in roadway work zones.

Cost-Benefit of Loss Control: Although the prevention of all losses is desirable, it is not always possible or economically feasible (Williams, 1985). Because many loss prevention measures reduce death or injuries, establishing engineering solutions or using cost-benefit analysis raises the ethical problem of measuring the benefits of saving human lives (Dorfman, 2005). This research project will allow for better identification of life-threatening risks associated with work zones and indentify areas which could benefit from the development of innovative risk mitigation strategies. It is known that crashes are the sources of direct and indirect costs. The direct costs are the obvious costs associated with the loss; the following is a list of indirect costs as compiled by Williams (1985):

1. Cost of time of injured employee;
2. Cost of time lost by other employees who stop work to help the injured worker;
3. Cost of time lost by supervisors or other executives preparing reports on the accident and training a replacement;
4. Cost of damage to machine, tools, or other property, or to the spoilage of material;
5. Cost to employer of continuing wages of the injured employee in full, after his return, even though the services of the employee (who is not

yet fully recovered) may for a time be worth half of their normal value; and

6. Cost that occurs in consequence of excitement or weakened morale due to the accident.

The following is a short list of the cost of loss-control measures as complied by Williams (1985):

1. Capital expenditures and depreciation on special construction features such as firewalls, and equipment such as sprinklers and hose extinguishers;
2. Expenses (salaries, fringe benefits, clothing, and training costs) for guards, safety supervisors, firefighters, consultants, engineers, and others directly involved in safety work.

Program expenses such as the cost of manuals and other training aids, employee time in training periods, inspections, and preventive maintenance are other loss control costs. Some costs associated loss control measures in specifically applicable to transportation projects might include: safety/awareness training, safety equipment, barricades, reflective and high visibility apparel, salaries of risk management personnel, and the cost of signage.

In such a manner the costs of implementing loss control measures can be weighted against the cost of the losses likely to occur without implementation of the loss control measures. Although developing a cost-benefit analysis of implementing a risk management program is not a part of this research, this section is included in order to emphasize the understanding that implementing any formal program will have costs associated with it. It is for the management of the organization to determine if such a program is economically feasible.

2.6.5 Resources available to the Loss Control Program

As mentioned several times in this section, loss-control is a subset of risk management; therefore the general template required to control losses is directly applicable to the process of risk management. Therefore, the resources available to loss-control are equally available to risk management. Crockford (1986) has created the following list of resources available to loss control managers as an alternative way of classifying approaches to any kind of loss control:

- Human resources - very good at detecting and correcting mistakes (managers, foremen, operators, engineers, technicians and office staff).
- Physical resources - devices used to prevent or to reduce the effect of loss.
- Organizational resources – opportunities to management that make loss control an integral part of the company's normal activities rather than an interruption to them.
- Educational resources - used in conjunction with organizational resources to make full use of human resources.
- Financial resources- financing and budgeting.

"Loss control is an excellent starting point because it does not require anyone to look beyond the activities in which they are themselves involved and on which they will all feel they are to some extent expert" (Crockford,1986).

2.6.6 Risk Management

As discussed earlier, the intent of this section is to show the development process for the management of risks. As with nearly every definition, there is variability in the definition of risk management depending on an author's perspective and functional area. However, for clarification, the transition from a loss control program to a risk management program involves the recognition and appointment of the risk manager. In the early 1950's risk management emerged from the revolutionary idea that someone within the organization should be responsible for "managing" the organization's pure risks (Vaughan, 1997). This means that risk management involves the application of general management concepts to a specialized area (Williams, 1985). More formally, risk management is a scientific approach to dealing with pure risks by anticipating possible accidental losses and designing and implementing procedures that minimize the occurrence of loss or the financial impact of the losses that do occur (Vaughan, 2001). Since predicting outcomes becomes less risky if you know more about a particular event (Dorfman, 2005), then any action that can economically be taken to reduce risk is worth taking (Crockford, 1986). The definition of risk management is well stated by Dorfman (2005): "Risk management is the logical process used by business firms and individuals to deal with their exposures to loss. It is a strategy for pre-loss planning for post-loss resources." Therefore, it is not merely the identification, measurement and treatment – which will be discussed at length as the standard risk management model—but the strategy or process by which to manage risks and control potential losses.

Risk management is the identification, measurement, and treatment of exposures to potential accidental losses and the purpose of risk management is to minimize the hurt at minimum cost (Williams, 1985). It is not enough to look only at individual risks, it is necessary to analyze loss-producing events and to find the aggregate of all the costs which may flow from them. The ultimate cost may be out of proportion with the apparent severity of the initiating cause (Crockford, 1986). For this dissertation multiple factors are identified and analyzed in order to ascertain the aggregate of all risks. The priorities which have been identified with respect to disaster planning have been adopted as equally viable conceptual priorities within the framework of integrated risk management for the mitigation of work zone crashes and fatalities (Vaughan, 2001):

- The first priority is to protect human life.
- The second priority is to prevent or minimize personal injury.
- The third priority is to prevent and minimize the potential damage to physical assets.
- The fourth priority is to restore normal operations as quickly as possible.

These priorities may also be considered when determining the objectives of the risk management program which it turn provides a basis for the risk management policy statement, as discussed in Chapter 4. The implementation of the priorities of disaster planning into the risk management approach for roadway work zones will provide the vital baseline from which to create a formal risk management model. However, before a formal approach can be developed it is necessary to determine the difference between formal and informal risk management.

2.7 APPROACHES TO RISK MANAGEMENT (Formal v. Informal)

The previous conceptions of risk management assume a structured approach. However, according to Smith (1999), that may not always be the case. The informal approach to risk management is where an organization manages risk in a subjective manner where judgment and claims rely heavily or entirely on personal consideration. In such a case, the organization frequently does not realize it is operating any kind of risk management procedure (Smith, 1999). The main danger is that this approach is deemed by the organization using it to be sufficient, however experience shows that it is not a sufficient approach (Smith, 1999). An example of informal risk management would be the establishment of a contingency fund, even though a project manager may not have any conception of where contingencies might arise, and how large the fund should be. In many cases organizations make up for a lack of risk management in the form of contingency funds. In contrast to the informal approach, the formal approach to risk management consists of a set of procedures that are structured along with established guidelines so they can be uniformly utilized by any member of the organization. This uniformity of approach ensures that objectivity is obtained by eliminating personal considerations produced by emotions and perceptions. Most authors recognize objectivity as an essential feature in the process of managing risks (Smith, 1999).

According to Smith (1999), “formalized procedures for the management of risk in projects are designed to suit the needs of the particular organization; hence there is no single methodology.” Therefore, the quality of a formal process of risk management is generally accepted to be dependent upon the following: (Smith, 1999)

- management awareness;
- motivation among project personnel;
- methodical approach;
- the information available (often linked to project phase);
- assumptions and limitations for which risk is based;
- qualifications and knowledge within the project; and
- experience and personality of the risk analyst(s) leading the project.

One assumption of this research is that the state highway agencies operate an informal risk management approach, in the planning, programming, design, and construction of highway projects. This is evidenced through the lack of formal guides establishing such practices and the general acceptance of a state-of-the-practice approach and the implementation of industry standards used as passive mitigating strategies. As stated earlier the intent of this research is to turn the existing approach into a formal process in order to ensure uniformity in the process.

2.8 STANDARD RISK MANAGEMENT MODEL

According to Dennenberg (1964), there are basically three steps involved in risk management:

(1) discovering the sources from which losses may arise;

(2) evaluating the impact on the organization or individual if a loss were to occur; and

(3) selecting the most effective and efficient technique to deal with the risks.

Vaughan (1997) describes a six step process:

(1) determination of objectives;

(2) identification of the risks;

(3) evaluation of the risks;

(4) considering alternatives and selecting the risk treatment device;

(5) implementing the decision; and

(6) evaluation and review.

Similarly, Crockford (1986) defines the logical process of risk management as:

(1) identification of risk/uncertainties;

(2) analysis of the implications (individual and collective);

(3) response to minimize risk; and

(4) allocation of appropriate contingencies.

Smith (1999) describes the standard risk management model, as it is commonly used in the United Kingdom, and divides it neatly into three parts: risk identification, risk analysis, and risk response (treatment). Risk identification is ideally carried out during the feasibility of the project, although it can be carried out at any stage of the project. If the project risks are identified in the initial (planning or concept) stage then the information can be used to choose between projects and options for a single project and establish constraints on the project. Once the risks have been identified they should be analyzed. Some of the risks which have been identified are quantifiable in terms of their effect on cost, time or revenue, and on the economic parameters of the project. There are three general types of risk response (treatment): risk avoidance or reduction, risk transfer and risk retention (Smith, 1999).

The Standard Model (Smith, 1999):

1. Risk Identification
2. Risk Analysis
3. Risk Response (Treatment)

This research project has chosen to take the standard model approach because it provides the flexibility required for the end user to develop specific techniques that are most appropriate for the specific industry. This research will develop the techniques required to apply the standard model to transportation projects and in particular, projects involving highway construction work zones. Techniques for the identification, analysis, and treatment of risks have been developed during the course of this research. Chapter 4 of this work will expand on the model development will provide greater detail into the specific approaches and techniques available to each of the three steps of the standard model. The results of this research will show the relationship of the standard model with respect to each stage of the construction project life cycle or project development process as defined by state highway agencies.

2.9 INTEGRATED RISK MANAGEMENT PROGRAM

Developing a risk management program that can be integrated into an existing management structure is the purpose of this research project. Procedures and models have established that specify a logical process of risk management that can be adopted by various firms or agencies; thus the intent of this research it to develop an integrated risk management model based on established "best practices." It is the intent of the research to develop a generic model that will best apply to construction projects and particularly to highway construction projects. It is goal of this research to develop a program that can be integrated into the existing management structures of construction firms, consulting firms, and state and local highway agencies. It is of great importance to the successful implementation of risk management that organizations understand that risk management is not an add-on but an integral part of the business (Merna, 2005).

The difference between the concept of risk management and integrated risk management is based on the desire of the organization at the upper echelon level to ensure unity of approach for all of its divisions. This means that it is no longer sufficient to manage risk at the individual activity level or in functional silos (Treasury Board of Canada, 2001). The Treasury Board of Canada (2001) has developed a framework for integrated risk management. The purpose of the framework is to improve decision-making by shifting to results-based management (i.e., prescriptive to performance). For the Canadians, integrated risk management requires looking across all aspects of an organization to better manage risk which leads to; a better use of time and resources, improved teamwork and strengthened trust through sharing analysis and actions with partners. An integrated approach to risk management leads to shared responsibility for managing risk (Treasury Board of Canada, 2001). Many authors have developed procedures for the implementation of risk management (Merna, 2005; Smith, 1999; Vaughan, 2001). It is with the ideology of eliminating the performance of risk management from functional silos that has driven this dissertation to develop an integrated risk management process. This research has utilized the best practices and recommendations from leading risk management authors from the United States, Canada and the United Kingdom in order to provide organizations and departments with a model that can be directly implemented into the existing management structure.

The risk management model that was developed in Chapter 4 of this dissertation was created from the basic framework of the risk management plan presented by Merna (2002). The basic premise of the risk management plan is to select appropriate controls or countermeasures to measure each identified risk. It must be understood that risk mitigation needs to be approved by the appropriate level of management. A good risk management plan should contain documentation for the treatment and a list of all responsible persons for those actions. The plan should also document the decisions about how each of the identified risks should be handled and it should also identify which particular countermeasure have been selected, and why.

According to Merna (2005); "Since the 1990's all of the proposals (for implementation) of risk management processes have included a prescriptive approach that involves a simple generic risk management process—identification, assessment, response and documentation." The proposed five phase generic scope includes; process scope, team, analysis and quantification, successive breakdown and quantification, and results (Merna, 2005) .The basic risk management plan developed by Merna (2005) is as follows:

RISK MANAGEMENT PLAN (RMP)

- Assignment of risk management responsibility;
- The corporate risk management policy;
- Risk identification documentation – risk register, initial response options;
- Risk analysis outputs – risk exposure distribution within the project, most significant risks, variation of project outcomes values with risk occurrences, probability distributions of project outcome values;
- Selected risk response options – risk allocation among project parties, provisions, procurement and contractual arrangements concerning risk, contingency plans, insurance and other transfer arrangements;
- Monitoring and controlling – comparison of actual with anticipated risk occurrences, control of the project with regard to the RMP;
- Maintenance of the risk management system – measures to update and maintain the RMP continuously and refine it; and
- Evaluation – recording risk information for further RMP cycles within the project and for future projects.

It is essential to understand the conceptual and practical differences between the standard risk management model and the integrated risk management plan. The integrated risk management plan encompasses the entire organization while the standard risk management model is concerned with the task at hand and it presumes that the management authority and risk tolerance is already addressed. At the project level or even at the project phase level the risk management cycle may look like a continuous loop: risk identification, analysis, control, and reporting (Kliem, 1997). As will be shown in the Chapter 4, the integrated risk management model developed through this current research project will have an element of required organizational structure and participation but it will also emphasize the standard model approach for each project phase.

2.10 HOLISTIC RISK MANAGEMENT

Since risk management has its origins in the finance and insurance industry, many authors consider the implementation of risk management as the management of pure risk for the purposes of controlling loss. While loss prevention or control is the overall goal of this research, it is necessary to emphasize that an organizational risk management program should look at all risks (losses or economic gain) within the same risk management structure. "Traditional risk management has been devoted to solving management problems associated with pure risks – the exposures that can only produce loss or no change. Holistic risk management implies that a program simultaneously considers all sources of loss. Holistic risk management combines traditional and financial risk management programs" (Dorfman, 2005). Therefore, it is understood that holistic risk management is the process by which an organization identifies and quantifies all of the threats to its objectives and manages those threats within (with some modifications) its existing management structure (Merna, 2005).

The depth of this research will be in the area of loss control and prevention during the construction of roadway improvement or enhancement projects namely in the form of mitigating crashes and fatalities in work zones. It will be the recommendation of future research to investigate all other risks with which agencies, departments, and organizations are exposed.

2.11 MINIMIZING RISK AND MITIGATING LOSSES

In the allocation of risks, it is important not to discourage designer innovation or to induce production of ultraconservative, defensive designs. Designers cannot innovate if placed in a position where the amount of their fees does not cover their risks, unless the owner will protect them as a means of encouraging new concepts (Fisk, 2006). The concept of minimizing risks and mitigating losses can be implemented initially by the adoption of a set of management policy positions that are vital to be success of the program. Whereas any one policy item may in itself appear to be somewhat insignificant, collectively they can save a company a considerable amount of trouble (Fisk, 2006). This research project integrated a risk management approach into the management structure of an organization under the premise that risk management is a special case of management and that all forms of management will have some degree of risk management (Crockford, 1986). In such an integrated approach, risk management becomes a proactive approach to identifying and responding to the “what if’s” that influence the project objective (Smith, 1999). Integration of risk management throughout the planning, design, and construction process is holistic, imposing discipline on those contributing to the project, both internally and on customers and contractors (Smith 1999). This process of decision-making based on defining the problem, evaluating possible solutions, selecting and implementing the optimal solutions, and monitoring the performance of a solution (Crockford, 1986) will be discussed in depth in the following chapters concerning the development of the integrated risk management model.

2.12 UNIQUE CONTRIBUTION OF THIS RESEARCH

This section will detail several studies similar to the research presented in the dissertation. Specifically, studies using an integrated risk management approach across all project development phases and studies examining work zone related risks will be reviewed. This dissertation expands on the qualitative assessment of risks utilizing the two dimensional risk matrix, a quantitative analysis using binomial regression and comprehensive full lifecycle risk program. Through the broad scope of these previous literatures, this dissertation will draw out relevant findings, consolidate the findings, and build on their strengths. The section closes with a statement of the unique contribution of the research presented in this dissertation.

Several important tools have been developed for use in the management of risks related to the transportation industry. The National Cooperative Highway Research Program (NCHRP) report 574— "Guidance for Cost Estimation and Management for Highway Projects during Planning, Programming, and Preconstruction"—is one such tool. The intent of this review is not to discuss the specifics of this report, but to give a general outline of the concepts behind the report. NCHRP report 547 is used to serve as a guide to prevent cost escalation through the life of the project to include: planning through preconstruction. This tool can be utilized at the organization level, program level, and the project level. Even though it is not explicitly viewed as a risk management program, it does integrate the need to identify, assess/analyze, and respond to risks associated with cost escalations during the project development. Essentially, this report identifies situations or conditions that would minimize the likelihood of a cost overrun. This is accomplished through a detailed assessment of each phase of the project development and the development of a guide to be followed by the management team to minimize the impact or likelihood of a project cost overrun. The purpose is to provide a method to increase the accuracy and decrease the variability of project estimates and cost estimates. NCHRP report 547 is similar to the research conducted in this dissertation in that it delves into the activities associated with each phase of the project development process for roadway projects: planning; programming and preliminary design; final design; advertise and bid; and construction phase. It emphasizes the need to identify and mitigate potential problems early on in the project and follow up on each potential problem during each successive project phase. It recognizes the need for project management functions and develops the understanding that risk management is a subset of project management. The NCHRP project created a number of "strategies" to be implemented throughout all phases of the project development to include: management strategy, scope and schedule strategy, off-prism strategy, risk strategy, delivery and procurement strategy, document quality strategy, estimate quality strategy, and integrity strategy.

The NCHRP 574 research differs from the present research by way of the implementation of a risk management program. The NCHRP project produced a guidebook for persons involved in highway projects in order to show best practices for cost control as related to each specific phase of the project lifecycle. This dissertation will move beyond these best practices to emphasize the importance of an overall project management structure in order to integrate a risk management program. This research has chosen to focus on the integrated risk management approach, while the creation of a project management program will be left for future research. NCHRP 574 has stressed the need for a strong project management team to fully implement the prevention of cost escalation; however the present research has developed the framework for the implementation of an integrated risk management program and has developed tools and techniques from which to identify, assess, and treat potential risks associated with vehicle crashes and fatalities in roadway work zones.

An additional resource which has approached the topic of risk management in highway projects is NCHRP 8-60. The main objective of NCHRP 8-60 was to develop a comprehensive guidebook on risk-related analysis tools and management practices for estimating and controlling transportation costs. The purpose of NCHRP 8-60 is to provide an approach to selecting tools and practices that support a systematic approach to risk management; is applicable to all project phases; and is applicable to all projects. It is essentially a "how to" manual for risk analysis and management practices. The essence of NCHRP 8-60 is cost control and cost estimation however, the system of managing the risk has important implications for the work of this dissertation. The NCHRP report accomplished its objectives by determining the current state of the practice through the use of a literature review and recent and on-going research results, along with federal requirements and guidance, and the current risk management practices related to cost estimation and control; recognizing the aspects of risk management as being risk identification, risk assessment (qualitative and quantitative), and risk response. NCHRP 8-60 chronicled eight case studies from California Department of Transportation (Caltrans), Washington State Department of Transportation (WSDOT), The US Department of Energy Office of

Environmental Management (DOE-EM), New York Metropolitan Transportation Authority (NY MTA), Ohio Department of Transportation (ODOT) and others. The results of the case studies were provided through a description of the risk management process; the method of identifying, analyzing, and responding to risks; and the method of risk monitoring and control for each of the case studies.

NCHRP 8-60 contributed greatly to the discovery of various tools and practices used for the identification, assessment, analysis, planning, and monitoring and control of risks. Among the identified tools and practices are:

- assumption analysis
- expert interviews
- Crawford slip (risk management participants write down one risk per minute for ten minutes)
- SWOT analysis (strength, weakness, opportunities, threats)
- checklists
- risk breakdown structures
- risk workshops
- probability and impact matrix
- three point estimate (technique for generating range estimates)
- beta value probabilities (categories of historical data are given confidence intervals)
- Monte Carlo analysis
- probabilistic cash flow

- schedule risk analysis software
- probability/cumulative mass diagrams
- tornado diagrams (rank project risks)
- self modeling worksheet
- risk priority ranking
- influence diagrams
- decision tree analysis
- risk map; risk comparison table
- fish bone diagramming
- risk register
- risk management information system
- risk management planning template
- detailed risk management plan worksheet.

Several of the risk management tools listed in first part of this chapter are also listed In NCHRP 8-60 and several of the practices identified by NCHRP 8-60 have been utilized in order to conduct this research, namely, assumption analysis, expert panel discussion (similar to expert interview), and checklists.…

The research included in this dissertation is similar to that conducted in NCHRP8-60 in that it focuses on the risk management process, it spans the entire project development process, and it categorizes risks into groups; however, while NCHRP 8-60 emphasizes the risks associated with project costs whereas, dissertation is focused on the risk of work zone vehicle crashes and fatalities. This dissertation provides a step by step template that decision makers can utilize in order to integrate a risk management program into the existing management structure, but it does not get into great detail about the automated tools that are available for the management of construction risks. However, this project does develop tools and methods that can be utilized during the brainstorming sessions of each project development phase.

Another resource which was called upon for a comprehensive review of risk management practices from an international perspective is the "Guide to Risk Assessment and Allocation for Highway Construction Management", Publication No. FHWA-PL-06-032. This is a report of findings from a team of representatives from the Federal Highway Administration, State Highway Agencies (SHA), industry, and academia. This report is a scan of risk management practices from Canada, Finland, Germany, the Netherlands, Scotland, and the United Kingdom. The results of the findings were developed into a risk assessment and management guide for implementation into the structure of highway agencies. FHWA-PL-06-032 acknowledges that few State Highway Agencies utilize formalized risk assessment or management programs. However it has been noted that Washington State Department of Transportation (WSDOT) and the California Department of Transportation (Caltrans) have developed cost risk assessment tools and a risk management program, respectively. This document is used to bring awareness to other SHA of the necessity of developing risk assessment and risk management programs.

Similar to the previous research topics, FHWA-PL-06-032 is geared to identify, assess/analyze, and treat (allocate) risk during each stage of the project development process: long-range planning and programming; preliminary engineering; final design; and construction. It emphasizes that risk management is repetitive and cyclical. The risk management process is described as: identification, assess/analyze, mitigate and plan, allocate, monitor and control, and back to identification (and subsequent activities). FHWA-PL-06-032 provides a generic process that can be applied by any organization regardless of the type of risk(s) that an organization wishes to manage. It provides a generic format to identify risks; to assess risks qualitatively using a two dimensional risk matrix that ranks the likelihood and consequence of a risk; to analyze risks using probability distributions for risks that are identified as "significant" during the assessment step; to identify mitigation strategies and plans; to allocate the risk to the party that is in the best position to manage the risk; and to monitor and update the risk management program. The FHWA-PL-06-032 report is similar in structure to the risk management portion of the literature review in presented in an earlier section of this chapter. The likelihood of this similarity rests in the fact that many of the sources cited in the literature review of this dissertation on the topic of risk management came from Canadian and European origin.

This dissertation utilizes a variation of FHWA-PL-06-032 in the standard risk management model described in Chapter 2 and again in the model development process described in Chapter 3. The research of this dissertation refines this model exclusively for the mitigation of highway vehicle crashes and fatalities by identifying, assessing and mitigating the hazards that are likely to increase either the frequency or severity of the risk of vehicle crashes.

Although this dissertation does not develop an automated method of managing risk associated with work zone crashes, it is the recommendation of this research to develop an automated method as a "future" research goal. Therefore this section has been included to discuss some recent work that has been conducted in the area of risk management for project schedules. Shatterman (2008) developed an integrated risk management methodology for planning construction projects under uncertainty. This method utilized a computer supported risk management system that allowed for the identification, analysis, and quantification of major risk factors along with the probability of occurrence and the impact on the project activity durations. Ultimately the research of Shatterman (2008) provides for a baseline scheduling with built-in protections against anticipated disruptions that may occur during project execution. This is accomplished by use of a graphical user interface that prompts the project management team to provide necessary data that can be used to determine the impact of a particular risk factor at the project activity level. The system allows for the computation of the probability of occurrence, and the impact of risk factors that are stored in a risk management database. Although this system is used for scheduling, this process could be adapted to include work zone hazards that have been identified in each project development phase. Because the system requires direct involvement of the project management team, it is best suited to manage those hazards/risks with the greatest uncertainty. This is accomplished by allowing the risk management team to make determinations of occurrence and severity for the specific project/activity and a risk assessment is made by weighting the consequences of identified risks with results of the database from similar projects. This dissertation makes use of database analysis to assess the frequency and severity of a number of identified work zone hazards Due to the limited amount of information contained in the statewide crash database, such a methodology is limited by the depth and accuracy of the database. The methodology for scheduling is somewhat complex but it is the recommendation of this dissertation to develop automated methods from which to manage the risks associated with work zone crashes. The result of such an effort could be in the development of a user friendly, time saving risk assessment method and risk database in order to develop a more quantitative approach to risk management.

Research from Zou (2006) at the University of New South Wales in Sydney, Australia confirmed the assertions of this thesis – that little research has been conducted in terms of stakeholder perspective in each phase of a construction project lifecycle. Zou (2006) states in his paper: “Previous research has mainly focused on examining the impacts of risks on one aspect of project strategies with respect to cost (Chen et al., 2000), time (Shen, 1997) and safety (Tam et al., 2004). Some researchers investigated risk management for construction projects in the context of a particular project phase, such as conceptual/feasibility phase (Uher and Toakley, 1999), design phase (Chapman, 2001), construction phase (Abdou, 1996), rather than from the perspective of a project life cycle. Moreover, little research has probed risks from the perspectives of project stakeholders.” The methodology for Zou’s (2006) research was in the form of a mail survey sent to industry practitioners: developers, project managers, contractors, consultants and engineers, and top management personnel. Zou (2006) acknowledged that his sample size (22 returns or 33% response rate) was relatively small but he determined it was because the “questionnaire aimed to explore 88 risk factors related to construction projects, which is time-consuming and may retard respondents from participation” and “the questionnaire content is broad and may not be within the knowledge context of some industry practitioners. The small sample may weaken the effectiveness of the questionnaire survey. However, the handpicked sample pool of industry practitioners and their profound knowledge and ample experience can compensate the aforementioned weakness.” Zou’s (2006) survey consisted of 88 risks that were identified by various sources (Chapman 2001, and others) and respondents were asked to indicate the likelihood (highly likely, likely, less likely) of occurrence and the level (high, medium, low) of impact on the project objective. Zou (2006) analyzed his survey results through the use of the risk significance index developed by Shen (2001). The risk significance index is a qualitative tool that is computed from the results of a survey of construction related risks as they pertain to stakeholders throughout the project lifecycle.

Zou (2006) utilized the following equation to calculate the significance score for each based on the respondent's assessment of the impact on a particular project objective:

$$r_{ij}^{k} = \alpha_{ij}\beta_{ij}^{k}$$

where: r^{k}_{ij} = significance score assessed by respondent j for the impact of risk *i* on project objective *k* ; *i* = ordinal number of risk, *i* is between 1 and 88; *k* = ordinal number of project objective between one and five; *j* = ordinal number of valid feedback to risk *i* which ranges from 1 to *n* where; *n* = total number of valid feedbacks to risk *i* ; α_{ij} = likelihood occurrence of risk *i* , assessed by respondent *j* ; β_{ij} = level of impact of risk *i* on project objective *k* , assessed by respondent *j* .

An average significance score was computed that considered the significance on the project objectives from all respondents. This average score is called the risk significance index score and was utilized to rank among all of the risks with respect to particular project objectives.

$$R_{i}^{k} = \frac{\sum_{j=1}^{n} r_{ij}^{k}}{n} = \frac{1}{n}\sum_{j=1}^{n} \alpha_{ij}\beta_{ij}^{k}$$

where; R^{k}_{i} = significance index score for risk i on project objective k. A three-point scale for α (highly likely, likely and less likely) and β (high level of impact, medium level of impact and low level of impact) were converted into numerical scales. Utilizing the instruction of Shen *et al*. (2001) and Wang and Liu (2004), "high" or "highly" is assigned a value of 1, "medium" is assigned a value of 0.5, and "less" or "low" is assigned a value of 0.1. The matrix presented in Table 2.11.1 displays the matrix of the risk significance indices.

Table 2.11.1—Matrix of Risk Significance Indices (Shen, 2001)

β / α	High level of impact (1.0)	Medium level of impact (0.5)	Low level of impact (0.1)
Highly likely (1.0)	1.00	0.50	0.10
Likely (0.5)	0.50	0.25	0.05
Less Likely (0.1)	0.10	0.05	0.01

Ultimately Zou (2006) ranked all 88 project risks using the risk significance index, and filtered out 20 key risks that influenced project objectives. He categorized the risks in terms of the management/control of the key risks by various stakeholders: clients (owners), designers, contractors, subcontractors, government bodies, and external environment (e.g. suppliers). Further, Zou (2006) allocated the key risk by project stakeholder, to specific phases of the project lifecycle. The result was a fishbone graph consolidating the interaction of stakeholders, project phases, and key project risks. This essentially provides industry professionals a way to identify key risks associated with the achievement of all project objectives in terms of cost, time, quality, environment and safety. Zou's (2006) research has many similarities to this dissertation, namely: (1) the identification of risks from the stakeholder's perspective, (2) the identification of risks in all phases of the project life cycle, and (3) the assessment of the identified risks. However, this dissertation differs in that it is specifically interested in the mitigation of work zone accidents and fatalities. Further, the current research goes several steps further to develop a quantitative risk assessment tool that is based on qualitative data. In addition, this dissertation develops mitigation strategies for each of the identified hazards.

There are several limitations to Zou's (2006) line of research which will be examined in greater depth in this dissertation. The method used by Zou (2006) may overlook certain hazards which could impact project objectives, namely, the method for calculating the significance index score may overlook those risks with a less likelihood of occurrence but a high level of impact on project objectives. These risks were not the focus of Zou's (2006) research, but should be taken into account in the risk management practice. This dissertation will allow for the identification of risks that have a high severity but a low likelihood, and likewise a low severity, but high frequency These hazards will be identified in such a way as to raise a "red flag" to risk managers.

Bai (2007) contributed to the knowledge and methodologies involved in the identifying safety deficiencies and developing effective countermeasures by relying on data from actual crash experience. Studying the characteristics of work zone crashes is the first step towards improving work zone safety (Bai, 2007). The investigation of actual work zone fatal crashes provides unique insight into the identification of specific work zone problems. Accordingly, effective mitigation strategies and countermeasures can be developed to limit the severity of work zone crashes, save lives, and contribute to a safer work zone environment. With this motivation, Kansas Department of Transportation (KDOT) carried out a project (KTRAN Project # KU-05-01) to study the fatal crashes in Kansas highway work zones between 1992 and 2004 to identify the characteristics involved. Utilization of the results of the study could be used for the development of mitigation and safety countermeasures. A four-step approach was used in the assessment including a literature review of previous work zone crash studies; a collection of crash data from the KDOT accident database and the original accident reports (A total of 157 fatal crash cases between 1992 and 2004 were examined.); a systematic analysis of the work zone fatal crashes using statistical analysis methods such as descriptive analyses and regression analyses; and the determination of the unique crash characteristics and risk factors in the work zone. Finally, improvements on work zone safety were recommended. This dissertation will also assess data through a database analysis, making recommendations for best practices for mitigation and work zone safety.

Past research has looked at several identified mitigation strategies to limit the severity of work zone crashes. Li (2008b) examined and attempted to quantify the effectiveness of several popular temporary traffic control (TTC) measures, including the use of flaggers/officers in the work zone; the use of stop signs/signals; flashers; no passing zones and pavement center/edge lines in reducing fatalities (severity) when a severe crash occurs and in preventing common human errors from causing work zone severe crashes. The current research does not attempt the quantification of mitigation strategies for the limiting of crash severity; instead it establishes a list of possible mitigation strategies to be used in each phase of the project lifecycle. Quantification of the effectiveness of such strategies is a direction for continued future research.

The emphasis of this dissertation is in providing stakeholders with a method for determining the importance of a work zone risk by determining both the likelihood and severity of a given work zone hazard. This is accomplished by looking at all severities of a given hazard. Past research has looked at the most severe levels of risk and has performed regression techniques to determine the effectiveness of mitigation strategies (i.e.: temporary traffic control methods) (Li, 2008b). Li (2008b) used binary logistic regression technique to evaluate the effectiveness of the certain traffic control measures in work zones. Binary logistic regression is a statistical method which describes the relationships between a set of independent explanatory variables and a dichotomous response variable.

The theoretical basis of the binary logistic regression method (Li, 2008b) of the KSU research is as follows: Y is considered an event (where Y = 1 and Y = 0 denotes occurrence and nonoccurrence, respectively); vector X is considered to be a set of predictors $\{X_1, X_2, \ldots, X_k\}$. The expected value of Y given X is the probability *(P)* of the occurrence of Y given X, which is expressed in linear regression form as:

$$E\{Y/X\} = P\{Y = 1/X\} = X\beta$$

Where; β is the regression parameter vector and $X\beta$ stands for $\beta_0 + \beta_1 X_1 + \ldots + \beta_k X_k$. The reasoning behind the logistic regression analyses as used to assess individual TTC methods is so that quantified estimations of the effectiveness of each temporary traffic control method can be obtained, with the actual effectiveness of these methods varying according to combinations with other traffic control devices and/or work zone conditions. Li (2008b) noted that this vein of research can be enriched by adding fatal crash data from other sources, examining crash data from states other than Kansas, and extending research by evaluating the effectiveness of the TTC methods to property-damage-only crashes. When possible, the evaluation should also consider data such as traffic volume and vehicle-miles traveled so that the effectiveness of temporary traffic control methods in reducing the total number of crashes can be determined and the effectiveness of certain combinations of TTC methods that are commonly used in work zones can be evaluated

The research identified in this section described the need to develop risk management models for the management of risks for transportation projects. The research that looked at risk from an integrated, lifecycle perspective focused on specific risks such as cost, quality, and time. None of the research on integrated risk management looked specifically at project lifecycle risks associated with roadway work zones. This section also described research that investigated project management tools for the identification, assessment, and allocation of risks. Several of the tools that were identified have been utilized in the development of this dissertation during the risk identification and mitigation phases of this research. This dissertation has developed and enhanced prior integrated risk management models by incorporating tools and methods from a business perspective, specifically the insurance and finance industry. In addition to lifecycle risk analysis, this section discussed the qualitative method developed by Shen (1997) to assess and rank highway project risk based on a risk significance index. This method would serve well to assess hazards that cannot be assessed by use of quantitative data. This will be a recommendation for future research. And finally, this section discussed the research conducted by Yong Bai (2007) at the University of Kansas that specifically predicts the probability of work zone fatalities and injuries using binary logistic regression methods with a set of predictors that have been used to evaluate the effectiveness of temporary traffic control methods. The approach to the research presented in this dissertation is similar to the approach used by Bai (2007) in that it utilized a state crash database to compile descriptive statistics of queried data, while Bai (2007) looked primarily at two severity levels (fatal and injury). Research presented in this dissertation investigated all severity levels (fatal, major injury, minor injury, possible injury, and property damage only) as compiled in the Iowa statewide crash database. This research also developed a unique method of assessing the likelihood and severity of vehicle crashes utilizing a two dimension risk matrix and work zone vehicle crash data.

2.13 CONTRIBUTIONS OF THIS RESEARCH TO INDUSTRY AND ACADEMIA

This research provides many contributions to the construction industry and the transportation industry. There has been little effort to create a formal integrated risk management model that incorporates all stages of the project life cycle. This model has direct application to any construction project and has the flexibility to be applied to an industrial setting with minor changes. There has been some research that has identified various risks during different stages of the construction project life cycle; however, none created a framework for integrating the model into an existing organizational structure, nor has any of the research developed a step by step approach to risk management. Much research has been conducted that identifies and assesses various construction and work zone risks. Many researchers have also identified factors and hazards that contribute to work zone crashes. However, none of the research has developed a checklist to be utilized by project managers and administrators to effectively manage risks associated within a particular project phase.

This research provides a framework for implementing an integrated risk management model into an existing management structure, it assists project managers with assembling a risk management team, it assists risk management teams by providing checklists and cues to identify and respond to risks associated with work zone crashes. This research also provides a quasi-quantitative method to assess the frequency and severity that a particular hazard poses on the risks associated with work zones. This project has direct application to industry and can be implemented immediately. It provides managers and agencies with a general framework that can be directly applied to the existing management structure. Once the model has been adopted by an organization various managers can assemble a risk management team at all levels of the corporation based on the recommendations of this research. Check lists, analysis tools, and countermeasures may be adopted from a wide variety of sources based on the preference of the risk management team and the risk tolerance level that has been adopted by senior management. Therefore, this model may be utilized by any organization for any risk classification by merely applying the standard risk management model to the desired risk classification.

Aside from offering practical strategies for use by contractors and designers, this dissertation creates a comprehensive quasi-quantitative analysis of risks using actual crash data supplied by the Iowa DOT. It identifies and prioritizes areas in need of future innovation and a pathway from the use of industry standards in mitigating risk. It fills gaps in the existing literature on the subject of risk management in highway work zones. In a move toward hybrid contracts, this dissertation provides an in-depth look at risks associated with the letting and award phases of highway projects. This dissertation will take a multi dimensional approach in the examination of work zone hazards through the application of a risk model incorporating multiple severity levels (fatal, injury and property damage only) and the corresponding frequencies.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The research objectives described earlier require a multi-faceted research approach entailing the use of construction management and administration functions for the purpose of risk management for all stages of a project lifecycle. This research is focused, in particular, on the mitigation of highway work zone crashes and fatalities. The framework for an integrated risk management program will be developed in Chapter 4 of this dissertation through the use of various sources obtained during the literature review. This chapter focuses the methodologies used to develop, validate, and apply the model specifically to risks associated with work zone crashes and fatalities. Several methodologies will be applied in the model development, and in its validation and application. With the exception of the risk assessment portion of this research, the methodology for this project is primarily qualitative. This was accomplished through the use of focus groups, surveys, personal interviews, and content analysis. Table 3.4.1 displays the matrix associating the research tasks with the corresponding research method.

Although crash mitigation planning for work zones is not specifically a public relations problem, this topic favors the applied research approach because it examines specific, practical issues (Wimmer, 2006). An integrated risk management approach uses stakeholder assessment and is similarly structured to a typical public relations research program in that consequences of actions are primary targets of interest, and the opinions of a cross section of individuals is desired. Within the constructs of applied public relations, strategic research is used to develop campaigns or programs that are used to help decide where the program needs to be in the future and how to get there (Broom, 1990). The bulk of the research performed will be modeled after public relations research.

A leading public relations text presents a four-step model for the research process: (1) define the public relations problem; (2) plan public relations program; (3) implement the public relations programs through actions and communications; and (4) evaluate the program (Cultlip, 1994). It is the intent of this research to create a program that meets these requirements. The research problem was defined in Chapter 1, which utilized crash statistics to emphasize the need to develop a strategy that implements a holistic approach to risks associated with highway work zones. It was during the initial stages of this research that the most logical strategy to mitigate risks associated with highway work zones was determined to be an integrated risk management program that could be implemented through existing management structures.

3.2 RESEARCH OBJECTIVES

The objective of this research is to develop a formal risk management model and to validate its usefulness for application in mitigation of work zone hazards. In order to accomplish this research objective, the preferred methodology favors a combination of qualitative research and analytic assessment that follows a path of content analysis, focus group, surveys and database analysis. The results of this research revolve around the implementation of the standard risk management model for each phase of the project lifecycle; risk identification, risk assessment, risk response (treatment). To best explore how the standard risk model will work in real life application, the research plan for this project was conducted in a similar three phase process: (1) model development phase, (2) the model validation phase, and (3) the model application phase. The following chapter, Chapter 4, will develop the integrated risk management model. Chapter 5 of this work will validate and detail the application of this model.

The model development phase of this research was exclusively qualitative. Through a detailed literature review and content analysis of existing research and literature on the subject of risk management, particularly in the area of highway work zone safety, a program for implementing integrated risk management within an organization was developed. The results of this phase also provided checklists and identification cues and techniques for the identification of work zone hazards throughout the phases of a highway project. Brainstorming cues for use by project stakeholders were developed by performing qualitative assessments of the results of the content analysis of papers and articles. This research led to the identification of five factors of work zone crashes and three primary causes of work zone crashes.

The model validation stage phase of this research involved qualitative assessments and an analytic quasi-quantitative assessment of work zone hazards. A risk assessment approach was chosen as opposed to a purely quantitative approach of risk due to the subjective nature of evaluating risks that have a high degree of uncertainty. This phase involved the implementation of a focus group of industry professionals to validate and to build upon the lists of hazard and associated project phases as identified in the analysis of past research. A survey instrument was employed to further validate the conclusions of the focus group. This research then assessed the frequency and severity of crashes based on the hazards as identified and validated. This was accomplished by developing an assessment strategy based on the analysis of statewide crash data provided by the Iowa Department of Transportation. The essence of this approach was spawned from the research conducted by Yong Bai (2007). The product of this assessment is a risk matrix that provides a quasi-quantitative understanding of the severity and frequency that a work zone hazard has on the risk of vehicle crashes.

The model application stage involves the application of the standard risk model through the use of the checklists, brainstorming cues, and the risk matrix tool in the identification and assessment of work zone hazards. These tools can be applied in much the same manner as conducted in the research for this dissertation in a real world scenario. In this research, the ultimate response to the potential risk of a vehicle crash in a work zone is mitigation (reduction). The identification of work zone hazards and the assessment and assignment of a risk score to each identified hazard aids in the prioritization of hazards requiring mitigation. A risk score is based on a combination of the relative frequency and relative severity of a hazard. A hazard with a high risk score or a high frequency or severity ranking requires a prioritized treatment (response) strategy. This was accomplished by responding to the hazard in the same way the standard risk management model responds to risk—accept, reduce, transfer or avoid. These "responses" were developed through the creation of hazard mitigation strategies for each phase of the project lifecycle. This was accomplished through the development of checklists generated from a focus group, surveys, and content analysis. During the content analysis, the mitigating source was identified in order to ascertain the phase of the project in which the mitigation strategy could be implemented—this concept is a contribution of this research to the risk management methodology for the mitigation of work zone crashes and fatalities.

3.3 RESEARCH GOALS

The goal of this research was to create the formal steps and actions that lead to the development of an integrated risk management model. In order to meet these goals it was determined the following questions needed to be answered throughout the research:

1. What is project administration?
2. What is construction project management?
3. What are the typical phases/stages of the project life cycle?
4. What activities are associated with each of the project phases?
5. How this process is modified for highway and roadway projects? (Project Development Process)
6. What is risk?
7. What is risk management? (Formal vs. Informal)
8. What is integrated risk management?
9. What is the standard risk management model?
10. What are the risks associated with work zone crashes?
11. What are the hazards/factors that influence crashes in work zones for each project phase?
12. How do these factors influence the frequency and severity of crashes?

13. What are the mitigation strategies or countermeasures for the hazards in each lifecycle phase?

However, in order to answer the previous questions, a set of tasks were created to specifically address each question. This allowed the researchers to determine the most effective research method to adequately respond to the questions associated directly with the stated goals of this research. The following task list defines the research requirements that are critical to this research project:

- Define management & administration
- Define construction management & contract administration
- Define the construction project lifecycle
- Explain the Construction Project Development Process for highway and roadway projects
- Define risk (as developed by insurance industry)
- Define risk management
- Develop integrated risk management model for construction projects
- Define the standard risk management model
- Develop checklist to identify hazards (during each phase)
- Develop cues to assist brainstorming
- Develop hazard assessment tool
- Develop hazard mitigation checklists
- Determine mitigation sources

- Determine construction phase(s) mitigation strategy will be implemented
- Create step by step risk management process

3.4 BACKGROUND AND MODEL DEVELOPMENT

As discussed in the previous chapter of this work, Chapter 2, a review of past research in the area of risk management and work zone safety laid the foundation for this project, serving the purposes of: (1) definition of terms, (2) identification of past research. Chapter 4 builds on previous literature to formalize an integrated risk management model.

3.4.1 Definition of terms

One of the primary purposes of the literature review was to define the terms that are paramount to this research. The literature review was arranged in order to progress from the concept of management and administration, through the project lifecycle, and conclude with the concepts and definitions of risk and risk management. The literature review was designed in order to facilitate the completion of the previous task list. Table 3.4.1 displays the matrix associating the research tasks with the corresponding research method.

3.4.2 Past Research

The secondary purpose of the review of past research was to identify similarities and difference of this research with others in terms of integrated risk management for transportation projects, and to identify research in the area of work zone hazards and mitigation strategies. Ultimately, this secondary purpose served as the “point of departure” for this research. This allowed the researchers to specify precisely where the research of this dissertation differs from past research and where the contributions of this research lie. Table 3.4.1 displays the matrix associating the research tasks with the corresponding research method.

Table 3.4.1 – Research Task Matrix

Research Task	Research Method	Source
Define Management & Administration	Literature Review	Multiple Authors
Define Construction Management & Contract Administration	Literature Review	Multiple Authors
Define the Construction Project Lifecycle	Literature Review	Multiple Authors
Determine project activities associated with each phase of Construction Project Lifecycle	Literature Review	Multiple Authors
Explain the Construction Project Development Process for highway and roadway projects	Literature Review	Multiple Authors
Define Risk	Literature Review	Multiple Authors
Define Risk Management	Literature Review	Multiple Authors
Define Integrated Risk Management	Literature Review	Multiple Authors
Explain the standard risk management model	Literature Review	Multiple Authors
Develop Integrated Risk Management Model	Literature Review	Multiple Authors
Determine Risk Associated with work zone crashes	Content Analysis	Multiple Authors
Identify key stakeholder for each phase of construction project life cycle	Content Analysis Focus Group Survey	Multiple authors Expert panel Industry leaders
Indentify Hazards – each phase	Content Analysis Focus Group Survey	Multiple authors Expert panel Industry leaders
Assess Hazards – create qualitative assessment tool based on quantitative data analysis	Crash Data Base analysis (quantitative research)	Yong Bai research (U of Kansas) Iowa Crash database
Determine Mitigation strategies – each phase	Content Analysis Focus Group Survey	Expert Panel Industry leaders

3.4.3 Model Development

The third purpose for the literature review was for laying the foundation for the development of an integrated risk management model specifically for roadway projects. For this research, the problem was stated to mitigate work zone crashes and fatalities. Using mitigation of work zone crashes as a starting point, previous research was reviewed and mitigation strategies were compiled. In general, the mitigating strategies are numerous and each source showed yet another approach and identified numerous factors which lead to accidents. Little evidence of a formal strategy to manage the mitigation strategies was revealed. The hodgepodge of ideas and strategies with no formality of implementation facilitated the need to approach the problem of work zone crashes from the perspective of the application of a business approach to risk management. A comprehensive literature review of books and journals with respect to the risk management approach of business revealed that the most effective method of project risk management was to utilize an integrated approach, meaning that the risks or threats are best managed within the existing management structure. This also emphasizes that risk management is implemented from the top management down and that ultimately the best approach to accident mitigation in work zones is through the project administration and management functions. Because project management covers all phases of the project, a management “tool” is necessary mitigate work zone accidents—namely risk management. The most effective manner to manage risk occurs when all stakeholders are on the same page. Therefore, an integrated risk management approach is utilized in order to create a team approach. When a project utilizes a formal risk management approach, it must encompass all phases of the project lifecycle, because the earlier a potential risk is identified, the easier it is to respond to the risk.

With such a framework in place, the next step is to refine the standard risk management model. It is at this point that this research project narrows its focus to work zone crash mitigation. Up until this point, the risk management framework is applicable to any project for any risk (i.e. financial, political). Focusing on a single risk category—work zone crashes—will allow for a greater depth of understanding of the practical application of the risk management model.

An exhaustive list of hazards contributes to work zone crashes. However, the key to understanding how to best identify these hazards in a highway project comes from a literature review of relevant risk management literature pertaining to the insurance industry and an understanding of the relationship between hazards, proximate cause, risk, and loss. A detailed understanding of the sequence of events that lead to a loss is necessary for the "identification" portion of the standard risk management model. This is essential in parceling out the factors (hazards) that lead to work zone crashes and to creating cues for the brainstorming template for risk identification. These cues are based on the understanding of "proximate cause"—the initial act which sets of a string of events that produce losses.

3.5 CONTENT ANALYSIS

Content analysis, in the case of this research, describes the method of the detailed examination various reports, studies, and papers which pertain to work zone crashes with the intent to extract a comprehensive list of the factors affecting and contributing to work zone crashes. In the content analysis, hazards, contributing factors, perils, and mitigation strategies were compiled from numerous research studies providing a composite list of such items in order to provide the initial layers of the identification and response checklists. The lists that were created using content analysis provided the basis for classifying the list into sources (components) of mitigation, mitigation methods and cues to assist brainstorming for identification of work zone hazards. Reviewing the lists generated from the literature review aided in the development of generalizations and mitigation concepts through the process of the extraction of significant factors or countermeasures that applied to this research.

Since the methodology of this research is identical to the proposed risk management model to be developed in Chapter 4, the starting point of this research was through creation of a checklist or prompt list that was used to stimulate ideas or thoughts about the risks associated with highway work zones—in particular the mitigation or control of crashes and fatalities. This checklist was created by the combined content analysis of research papers, journal articles, along with various transportation agency memoranda. Articles and papers were identified based on their direct applicability to work zones and the management of risks associated with vehicle crashes and fatalities. Ultimately a list of hazards was created using multiple sources. Each hazard was entered into a table along with the name of the author (See Tables 5.3.1-5.3.5 in Chapter 5 of this dissertation). Many of the hazards were repeated several times and the variations of the hazard were included to show the perspective of the particular author/researcher. The purpose of the checklist was to serve as a starting point for the research, allowing for the development of the risk identification and response (treatment) template to be utilized during the focus group discussion.

3.6 FOCUS GROUP

The focus group served several purposes, namely to identify stakeholders in each stage of the construction project lifecycle as it applies to highway projects and to identify hazards and countermeasures (mitigating strategies) associated with work zones crashes in each stage of the construction project life cycle or Project Development Process as defined by state highway agencies. The focus group consisted of members from academia, industry, and state and federal highway agencies. The following is a list of the twelve members of the focus group that conducted an expert panel discussion in October 2008:

- Kelly Strong Iowa State University
- Jennifer Shane Iowa State University
- Douglas McDonald Iowa Department of Transportation
- Donald Meeker Iowa Department of Transportation
- Troy Jerman Iowa Department of Transportation
- Thomas H. Maze Iowa State University
- Jerry Roche FHWA (Federal Highway Administration)
- Mark Bortle Iowa Department of Transportation
- Jeff Koudelka Iowa Plains Signing, Inc.
- John Smythe Iowa Department of Transportation
- Thomas J. McDonald CTRE (Center for Transportation Research and Education)
- Daniel Enz Iowa State University

The intent of the expert panel discussion was to gather feedback from the preliminary research and to assist researchers with the development of a formal risk management program. The following is a list of the expert panel objectives; however, due to time constraints the emphasis of the focus group concentrated on tasks 2, 4 and 5:

1. Create the framework for an integrated risk management model;
2. Identify activities, tasks and considerations associated with each stage of a typical project;
3. Identify stakeholders for each stage of a typical project;
4. Create a checklist of potential hazards/risks (related to work zone accidents) that are typically associated with each stage of the project; and
5. Create a list of possible strategies to manage each of the identified hazards/risks for each stage of the construction project life cycle.

This was accomplished by introducing the focus group members to the research through a thirty minute presentation that described the overall research and the objectives of the expert panel. Each participant was provided a handout which detailed each phase of the construction project lifecycle. The CSI (Construction Specifications Institute) format was utilized as a preliminary generic tool to represent the stages of the project lifecycle; aiding panel members to provide information that relating to the project lifecycle in terms of the Project Development Process as understood by state highway agencies. During approximately four hours of group discussion, the expert panel systematically went through each stage of the construction project lifecycle starting with the concept phase and concluding with the construction phase. For each of the phases, expert panel members identified potential hazards that were likely associated within each phase, and identified mitigating strategies or countermeasures that could be implemented in the corresponding project stage. This process also provided a forum for panel members to express concerns about or to provide recommendations to the ongoing research and future research.

The information gathered during the literature review and content analysis was instrumental in detailing the activities associated with each phase of the project lifecycle or project development process, allowing for the focus group discussion to concentrate on the hazards associated with each phase. In addition, a portion of the discussion focused on the activities associated with each project phase and on the identification of stakeholders for each phase. This information (phase activities & stakeholders) has been provided in Appendix C.

3.7 SURVEY

The product of the focus group was a comprehensive list of mitigation strategies that applied to the specific hazards identified in the previous section of this research. Appendix C shows the results of the expert panel discussion for each phase of the project development process. The results of the focus group were arranged into the form of a questionnaire facilitated by Zoomerang®, an on-line survey provider. The survey asked respondents to agree or disagree with the statements pertaining to hazard identification during each stage of the project development process (planning & programming, design, letting & award, and construction). Respondents were asked to identify their area of expertise and the on-line survey directed them to the portion of the survey that represented the respondent's specialty area. Respondents were allowed to participate in only that portion of the on-line survey. The purpose of the survey was to validate that risks, hazards, and countermeasures (mitigating strategies) were properly identified for each phase of a highway project. The surveys were distributed to select electronic mail contact lists from government agencies, industry, and academia in order to ensure that only the opinion of “experts” were provided in the results. This was done in order to reduce the variations that might occur in survey results as a consequence of non-expert participation.

3.8 DATABASE ANALYSIS

The integrated risk management model was further validated through a descriptive statistical analysis of Iowa crash data that had been compiled electronically from the years 2001 to 2008. This data analysis was performed using a methodology similar to the one utilized by Yong Bai at Kansas State University, in 2007. The analysis employed the same factors relating to work zone crashes as indentified by Dr. Bai (2007) to establish the extent to which the identified hazards increase either the frequency or severity of a work zone crash. The identified hazards from the focus group study were prepared and correlated to factors which could be assessed using data from the Iowa statewide crash database. The database was queried to list data pertaining to work zones as documented on the investigating officer’s report. The purpose of the database query was to develop a methodology that could be utilized to use actual crash data to provide a quasi-quantitative assessment of each hazard as identified in the previous section of this research. In order to get a feel for the data, a query was created to gather data for all severity levels of work zone crashes as provided in the Iowa Department of Transportation—Saver Crash Data from the Office of Traffic and Safety. The data from 2008 was preliminary and may not be fully inclusive of all crash data for that year but was included in this research because the general nature of crashes provides the adequate randomness required to provide the most representative data set. The most difficult part of the risk assessment of the identified work zone hazards was the collection of relevant crash data to provide the most applicable representation of the hazard as it pertains to the many coded entries on the investigating officer’s report. Appendix F provides a copy of Form 433033 from the Iowa Department of Transportation “Investigating Officer’s Report of Motor Vehicle Accident” utilized by the responding officer. It is this report and the accompanying codes and description of driver characteristics, vehicle characteristics, road characteristics, operating environment, and work zone conditions which was used to cull the needed data and to correlate the data fields with the identified hazards of interest. Unfortunately, the report is formatted to accommodate the investigating officer and not necessarily the transportation researcher; therefore, the factors that influence crashes are not explicitly listed on the report form in all cases. Therefore, careful consideration was expended in order to extract the most applicable data field variables that most closely represented the underlying concern of the identified hazard. This process was found to be the most exhaustive component of the risk analysis process. The subjective nature of aligning an identified hazard to the available data variables of the crash report is a noted concern. However, the intent of this research is to develop a methodology that can be utilized to formalize the risk management of work zone crashes and fatalities and it is understood that the nature of risk management depends on the ability to standardize the approach to managing risk. Therefore, the decision making process must take into account the limitations of the data, while at the same time, providing a reasonable correlation between the identified hazard and the data variable(s). As discussed in the previous section, during the risk identification process, upon listing potential risks or hazards, the risk should be classified or grouped in order to aid the analysis and risk response functions.

During the analysis of work zone hazards it was determined that there are essentially five groups or factors that influence the rate and severity of work zone crashes; driver characteristics, vehicle characteristics, road characteristics, operating environment, and work zone condition. Through the use of these factors or group classifications, several of the fields on the investigating officer's report were grouped for the purpose of aligning the identified hazard with the appropriate field in the accident report. The field names and values for the database are provided in Appendix G of Chapter 5, provides more information about this assessment process. For some of the identified hazards, the data fields needed to be combined in order to properly categorize the risk. For instance, construction vehicle traffic has been identified as a work zone hazard and has been classified or grouped as a work zone condition; therefore, since construction vehicles are identified by the cargo body in the crash database, the data field for the cargo body was combined with the data field for the roadway contributing circumstance with the value corresponding to work zones. This assumes that vehicles with construction type cargo bodies involved in crashes that have been reported as work zone related roadway contributing circumstances and this process infers that the combination of these two fields will yield a condition for assessing construction vehicle traffic. For this research, only the data fields for construction vehicle traffic were combined to represent a specific condition; all other hazards were represented by only one data field.

In some cases it was necessary to represent a hazard that has been grouped in one classification by a data field that has been grouped by a different classification. For instance, “traffic congestion & delay” has been identified as a work zone hazard. Traffic congestion is classified as “operating environment,” however, the crash report does not have an entry for traffic congestion, therefore, the assumption was made that evasive action (presumably from stop-and-go traffic) best represented the conditions of the hazard. However, evasive action is classified as a “driver characteristic” and not “operating environment.” This research qualifies that subjective observation must be implemented in cases where the crash report may not explicitly represent identified hazards. The concept of the research is to develop the best approach to assessing hazards. Hazards assessed within the confines of objectivity based on basic assumptions are preferred to qualitative assessment based on an “educated guess”.

The work zone data used in the analysis was compiled by Dr. Michael Pawlovich of the Iowa Department of Transportation from a larger statewide data base. This data was provided in the form of a database file or .dbf. Microsoft Access® was utilized to design queries that extracted data from specific data fields as provided on the motor vehicle accident report. In all, over 2400 queries were designed to extract data from January 2001 through October 2008 database files. For each query, specific fields were identified and parameters were specified based on the desired output. The general requirements for each query were crash severity, vehicle number (the number of vehicles involved in each incident), and the field(s) of interest that best represents the identified hazard. Queries were performed to count the number of crashes for each of the five crash severity levels for each of the eight year periods that correspond to the data field that best represents the work zone hazard.

A risk assessment tool was created to provide an analytic guide to risk assessments based on quantitative data provided from the statewide crash database. The descriptive statistics of data queried from the statewide crash data base was utilized to evaluate the severity and frequency of vehicle crashes with specific characteristics. The severity and frequency of those crashes were "normalized" against all statewide work zone crashes in order to get a relative comparison of crash severity and frequency that a particular hazard poses on a work zone. This was accomplished through the development of a two dimensional risk matrix for the assessment of the frequency and severity which a hazard may impart onto the risk of vehicle crashes.

The developed process converts the frequency and severity of crashes that were identified earlier in the project into an "average crash severity ratio" and "relative frequency" that are subsequently ranked on a scale from one to five as shown on the horizontal and vertical axes of the risk assessment matrix. Brackets for each of the five rankings for the severity and frequency of vehicle crashes were developed using a normalized frequency distribution of the extracted crash data. For this research, a transformation was performed on the data, and the mean and standard deviation of the distribution was utilized in order to divide the distribution into five segments. The brackets aid in the plotting of each identified risk according to relative frequency and severity in order to assign a risk score to each assessed hazard.

3.9 SUMMARY

The remainder of this work will employ the methodologies as described herein for the purposes of model development, model validation, and model application for the mitigation of work zone crashes and fatalities. The following chapter, Chapter 4, will go into detail to explain the process of developing and integrating a risk management program. Chapter 5 will provide the validation and application for the integrated risk model.

CHAPTER 4

RISK MANAGEMENT MODEL DEVELOPMENT

4.1 INTRODUCTION

This chapter will develop an Integrated Risk Management Program to be recommended for implementation by organizations and agencies that engage in construction activities. The concept of this program is generic but has been organized in such a way to give preference to the transportation industry and organizations that implement and administer transportation projects. An integrated approach to risk management suggests that there are multiple specialty groups, multiple levels of management, and multiple project phases that need to be bridged within the risk management model. In doing so, large/complex organizations or partnerships of multiple organizations will largely benefit from the formation of such a risk management program. However, the emphasis of this program is on communication and teamwork, therefore, regardless of the size or complexity of the organization, the following template for integrated risk management may be utilized and adapted by any organization interested in managing project risks.

Chapter 2 discussed in detail the project lifecycle for the general construction industry and the project development process typically utilized by state highway agencies. The model developed in this chapter will highlight the development of an integrated risk management approach that is intended to provide risk management expertise to a specific task or project phase while meeting the needs of the organization and providing and sharing information with stakeholders in different functional areas and project phases.

Contained within this chapter is the combination of "best practices" and recommendations that have been published by noted authors and organizations from throughout the United States, the United Kingdom, and Canada. A comprehensive review and compilation of prior research and published procedures has resulted in the organization and development of a step-by-step process for agencies and organizations to develop and integrate a formal risk management approach into their existing management structure with minimal disruption to the organization. The key to the success of implementation of this program within an organization is dependent on the commitment from and involvement of senior levels of management. The flow of this chapter and the integrated risk management model will start at the corporate or senior level, through the development of organizational policy. It will then proceed to the selection of a risk management "champion." This chapter will describe the characteristics of the risk management authority and will provide "best practices" in assigning the appropriate risk management responsibility primarily at the project level, but also at the organizational level depending on the needs of the organization. This model will then describe the need to include or develop the project definition. In most cases the project definition is developed in the planning and programming stages; however, the project objectives and consideration are required for the management of risks identified in all phases of the project lifecycle. The project definition will provide the risk management team with information needed to control various project risks. This model will then apply the three step standard model to each of the project phases. This process will involve the selection and implementation of a risk management team from a list of stakeholders for each project phase who are identified prior to applying the principles of the standard risk management model. All information from each project phase is then documented, compiled and shared at the senior management level. The information gathered from previous project phases is to be utilized to assist risk management teams in subsequent project phases. All information gathered during the application of the standard risk management model will be recorded and documented into a risk log or risk register. Finally, the risk management program will be evaluated and improvements to the program will be recommended.

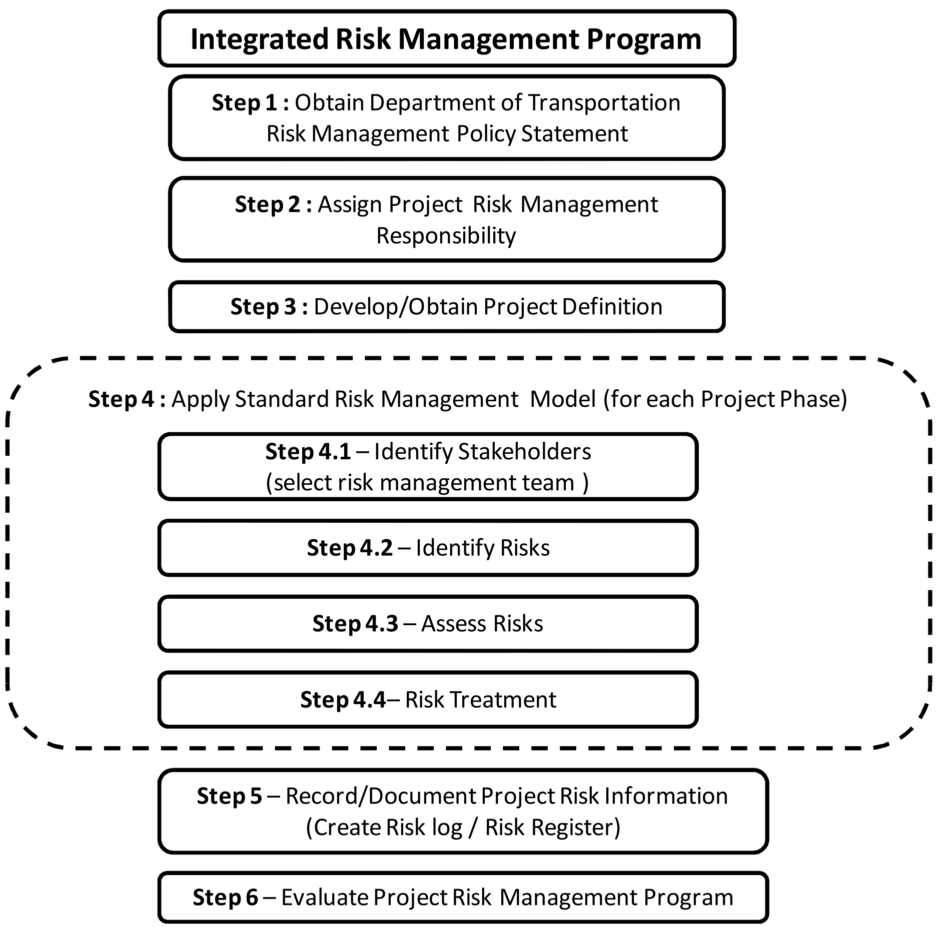


Figure 4.1.1 – Basic Model of the proposed Integrated Risk Management Program

4.2 INTEGRATED RISK MANAGEMENT

Chapter 2 discussed definitions associated with risk and risk management. This section will provide additional insight into the process and will formalize the general approach to developing a risk management program. The general framework for implementing a risk management program may require organizations and agencies to adjust their corporate policy in order to facilitate a method of integration. As detailed in Chapter 2, risk management is the logical process used by business firms and individuals to deal with their exposures to loss. It is a strategy for pre-loss planning for post-loss resources (Dorfman, 2005). Integrated Risk Management is an explicit and systematic approach to managing strategic, operational and project risk to organizational objectives, from an organization-wide perspective (DFO Canada, 2004). However, risk management must not become just another bureaucratic task which steals time (Smith, 1999). It is important that companies understand that risk management is not an add-on but an integral part of the business (Merna, 2005). Merna (2005) suggests that by accepting "best practices" at each organizational level many of the risks emanating from poor practice will be alleviated. Therefore, "the Integrated Risk Management Framework advances a citizen focus by strengthening decision-making in the public interest and placing more emphasis on consultation and communication" (Treasury Board of Canada, 2001). Smith (1999) advances the importance of the strength of communication and decision-making among the members and stakeholders of the project team and warns that the risk process should focus on spending time in the identification and response phases, and not on the creation of advanced mathematical models of the project. The identification of risks and opportunities for a project should be based on the objectives of a particular project and the objectives of the organization (Merna, 2005). This concept is discussed in step one of the risk management process below. The idea that effective risk management cannot be practiced in isolation, but needs to be "integrated" into existing decision making structure and processes cannot be over-emphasized. "As risk management is an essential component of good management, integrating the risk management function into existing strategic management and operational processes will ensure that risk management is an integral part of day to day activities" (Treasury Board of Canada, 2001).

The following is an outline of the procedures involved in implementing the basic model for an Integrated Risk Management Program as developed for application to construction projects and organizations that specialize in the development of transportation facilities:

Integrated Risk Management Program

1- Obtain Organization's Current Risk Management Policy Statement

- Top Management Responsibility
- Objectives and Strategies
  - Risk Management Profile
  - Goals & Priorities
  - Risk Tolerance
- Duties and Responsibilities

2- Assign Project Risk Management Responsibility

- Attributes
- Qualifications
- Classification/wage grade
- Delegation parameters
  - PM's
  - Seniority
  - Experience

  - Knowledge
- Existing decision making authority
  - Subordinate authority at each phase (phase manager)
- Existing project delivery system and approach
- Existing project documentation system

3- Develop/Obtain Project Definition

- Goals
- Considerations
- Project Information
  - Traffic volumes
  - Closures
  - Anticipated events
- Update as information is obtained
- Determine if goals are realistic (Smith, 1999)

4- Apply Standard Risk Management Model for each project phase

- Delineate project phases
- Conduct weekly meetings (existing standard operating procedure (SOP))
- Make risk part of every meeting agenda
- Distribute and archive meeting minutes (see steps 5 and 6 below)

4.1 Identify Stakeholders (select risk management team)

  - Activities
  - Stakeholders
    - Risk management team
    - Risk manager

4.2 Identify Risks

  - Hazards
    - Events

- Factors
- Risks (losses)

4.3 Assess Risks

4.4 Risk Treatment

5- Record/Document Project Risk Information (create risk log/risk register)

6- Evaluate Project Risk Management Program

4.3 RISK MANAGEMENT POLICY STATEMENT (STEP 1)

The concept of risk management can only be accepted and practiced by an organization if there is a conscious introduction of its guiding principles (Crockford, 1986). In most cases, it is the board of directors and the professional managers who are responsible for the preservation of the organization's assets (Vaughan, 2001). This means the top management must be fully committed to the risk management principles and this commitment must be expressed in the form of a policy statement. Typically, policy statements are created or promulgated by the top management and define the risk management objectives along with the duties and responsibilities of the risk manager (Williams, 1985). A risk management program begins with a statement of general objectives which is followed up with a statement of principles and procedures designed to achieve its objectives (Dorfman, 2005). Since the development of a risk management statement cannot be generated by someone outside of the organization (Vaughan, 1997), a brief overview of the elements of a risk management policy statement is included herein in order to assist agencies and organizations with the development of a risk management policy statement. As shown in Figure 4.3.1, the basic elements of a Risk Management Policy Statement are: (1) top management emphasis, (2) the objectives and strategies of the risk management program, and (3) the duties and responsibilities of the risk managers and/or risk management department.

Figure 4.3.1 – Elements of a Risk Management Policy Statement

4.3.1 Objectives and Strategies

In order to be effective, "risk management needs to be aligned with an organization's overall objectives, corporate focus, strategic direction, operating practices, and internal culture" (Treasury Board of Canada, 2001). This can be accomplished by combining the corporate risk management profile, the risk management goals and priorities, and the accepted risk tolerance or retention limit (Vaughan, 1997, Williams, 1985). As a starting point in the development of a risk management policy statement, there are several considerations that are essential to obtaining the organization's objectives.

Risk Profile: In building the corporate risk profile, information and knowledge at both the corporate and operational levels is collected to assist departments in understanding the range of risks. The information provided will include the likelihood and severity of the potential impacts of the risk (Treasury Board of Canada, 2001). This information can be obtained by performing an environmental scan of the organization where the current state of risk management within the organization is assessed by evaluating the policies, tools and methods being used. Such a scan may increase the organization's awareness of the key characteristics and attributes of the risk it faces. Such attributes and characteristics of risk may include (Treasury Board of Canada, 2001):

- **Type of risk:** technological, financial, human resources (capacity, intellectual property), health, safety;
- **Source of risk:** external (political, economic, natural disasters); internal (reputation, security, knowledge management; information for decision making);
- **What is at risk:** area of impact/type of exposure (people, reputation, program results, material, real property);
- **Level of ability to control the risk:** high (operational); moderate (reputation); low (natural disasters).

Goals and Priorities: The organization's goals and priorities in terms of the risk management program are an integral part of the development of the risk management objectives and strategies. This means that the goals of the risk management program must align with organizational objectives. For most organizations, the goals and priorities of the risk management program include the following: preserve human life and property; preserve the operating effectiveness of the organization; preserve the ability to achieve organizational goals; control costs; preserve public relations, and others (Vaughan, 1997). As discussed in Chapter 2, the priorities for disaster planning at the organizational level, strongly resemble the understood priorities of state highway agencies and the construction industry in terms of crash and fatality mitigation in work zones. Vaughn (2001) lists the priorities of disaster planning as follows:

- The first priority is to protect human life.
- The second priority is to prevent or minimize personal injury.
- The third priority is to prevent and minimize the potential damage to physical assets.
- The fourth priority is to restore normal operations as quickly as possible.

Risk tolerance: In the insurance industry the term risk tolerance would likely be generalized by risk retention limit. This is the limit to which the organization would be willing to retain the exposure to loss (Vaughan, 1997), meaning that the likely treatment of the risk would be to avoid, transfer, or reduce (mitigate) the risk. In general, there is lower risk tolerance for the unknown, where impacts are new, unobservable or delayed. Likewise, generally, there are higher risk tolerances in instances or situations where people feel more in control. An example of this is the higher risk tolerance which many people have for automobile travel than for air travel (Treasury Board of Canada, 2001). To be useful the policy statement must specify the maximum limits of exposure in order to provide the risk manager with guidance on the best treatment for the risk (Vaughan, 1997). Determining and communicating the risk tolerance of an organization is an essential part of managing risk.

This process identifies areas where minimal levels of risk are permissible, as well as where higher, yet reasonable levels of risk are acceptable (Treasury Board of Canada, 2001).

4.3.2 Duties and Responsibilities:

This risk management policy statement should clearly explain the concept of risk management and the benefits that it brings to the organization. The policy statement should spell out the responsibility and accountability of each line manager to include the full support of the policy and it should spell out the need to manage risks within his/her area of authority (Crockford, 1986). Step 2 of this model provides the general requirements and attributes of the risk management responsibility. See a sample risk management policy statement in Appendix A

4.4 ASSIGN PROJECT RISK MANAGEMENT RESPONSIBILITY (STEP2)

The assignment of project risk management responsibility could and should be made at the organizational level; however, at the least it is necessary to assign a risk manager at the project level (Crockford, 1986). Appointment of a risk manager is an essential aspect of introducing risk management to an organization. The use of the term "risk manager" may not accurately describe the true function of the job. "It is far more descriptive of the real function in the organization to describe the risk manager as an advisor, for they are there to advise, help, persuade, and encourage others to manage the risks of their particular part of the organization, not to manage overall organizational risks" (Crockford, 1986). Among the tasks which the risk manger will need to be involved in are the following:

4.4.1 Assessment: The risk manager has the responsibility to assess the existing situation, making it essential that the assigned risk manager be familiar which the particulars of the scope of the project to which he/she is assigned risk management responsibility. The risk manager needs to be aware of the objectives and policies of the organizations such that the purpose for such assessment is clearly understood. Many project managers perform risk analysis solely because somebody else (client, parent company, government) has told them to do so. The analysis is often done in a hurry with its primary purpose intended for use as an alibi in case things should start to go wrong (Smith, 1999).

4.4.2 Communications: Communicating the purpose of the risk management and its importance in benefitting the organization and meeting the needs and objectives of the organization and the project is an important function of the risk manager. In addition, the risk manager needs to ensure that project personnel achieve a high degree of involvement in the identification and quantification phases and the results emerging from the analysis. It is crucial for project personnel to identify with the goals of risk management, to see the benefits, and to want to succeed by using risk management as a project monitoring and control tool (Smith, 1999).

4.4.3 Motivation: Fundamentally, the key to successful risk management lies in the attitudes espoused by the organization toward risk management and the communication of such attitudes to the people within the organization. The key to achieving a proactive risk management attitude within a company relies first of all on the people involved (Smith, 1999). Whatever the organizational structure within which the risk management process is undertaken, it must be supported or “championed” by the highest levels of management or it will not have access to the requisite information, neither will the organization be likely to benefit from its recommendations (Merna, 2005). Key factors within an organization which contribute to successful implementation of a risk management program include: management attention, motivation, insight, openness and key personnel involvement and learning. These factors should be combined with a risk management methodology focusing on participation, ownership and responsibility (Smith, 1999). Organizations can leverage existing capacity and capabilities (e.g., communications, committee structures, existing roles and responsibilities, etc.) to provide the motivation and ownership of risk management functions within the organization (Treasury Board of Canada, 2001). Strategies which can be applied within management structures include:

- Seeking excellence in management practices, including risk management;
- Encouraging senior managers to champion risk management;
- Encouraging innovation, while providing guidance and assistance when things do not turn out as expected;
- Encouraging managers to develop knowledge and skills in risk management;
- Including risk management as part of employee performance appraisals;
- Introducing incentives and rewards; and
- Recruiting on risk management ability as well as experience.

4.4.4 Facilitation: Specialized training in risk management is a desired attribute for a risk manager (Dorfman, 2005). A risk manager should possess experience as a strong facilitator or should appoint an experienced facilitator to chair meetings where potential risks are identified and addressed (Merna, 2005). In instances where a breadth of risks are included in the assessment, a management staff should be headed by a manager with overall responsibility. The staff should include one or more of the following positions as related to specific risks associated with the project: insurance expert, financial risk manager, claims manager, loss control engineer, employee benefits specialists, and financial analyst. The participants in the identification of risks associated with the project should include individuals responsible for carrying out the project and those having a firm grasp of the business and technical aspects of the project and the risks confronting it from within and outside the organization (Merna, 2005).

4.4.5 Project Management: Project management encompasses broad responsibilities falling into three categories: responsibility to the parent organization, responsibility to the project and the client, and responsibilities to the project team (Merna, 2005). In terms of risk management, project management involves addressing all possible risks, mitigating, reviewing and documenting the risks as work progresses (Merna, 2005). The project manager will assess risk in the individual projects, but will report to the next level if significant impacts on the overall strategy and cost are foreseen (Merna, 2005). Managing the transfer of risks within the project is an important function of the risk manger. Some risks may be transferred to others by contract, however, it should be recognized that almost all risk not expressly transferred or assumed by another party for fair compensation are retained by the owner. The principle guideline in determining if a risk should be transferred to another is whether the party assuming the risk has both the competence to assess the risk and the experience necessary to control or minimize it (Fisk, 2006).

4.5 DEVELOP/OBTAIN PROJECT DEFINITION (STEP 3)

The better the informational foundation of the risk management process, the more accurate the results. This is accomplished by gathering existing information about the project including its scope, objectives and strategy (Merna, 2005). This process is essential in establishing a shared understanding of the project among all of the parties involved. The client's objective in pursuing the project must be clearly stated and agreed upon by senior management early in the appraisal phase, as everything that follows is directed at achievement of these objectives in the most effective manner (Smith, 1999). Implementation of a risk management program beginning at the earlier stages of the project life cycle will yield best benefits, however continuity may be lost between project phases if the risk management program is initiated prior to the project definition being established (Merna, 2005), thus making the project definition a necessary component for the success of the risk management process. The first stage in any risk management process is also the first stage of the qualitative assessment of risk—review of the project programs and budgets to ensure that they are realistic to meet the project objectives (Smith, 1999).

4.6 APPLY STANDARD RISK MANAGEMENT MODEL FOR EACH PROJECT PHASE (STEP 4)

The standard model is divided into three parts: risk identification, risk analysis, and risk response. Risk identification is ideally carried out during the appraisal of the project, although it can be carried out at any stage of the project. In the project, risks are identified at the appraisal stage then the information can be used to choose between projects or between options for a single project as well as to establish constraints on the project. Once the risks have been identified they should be analyzed. Some of the risks which have been identified are quantifiable in terms of their effect on cost, time or revenue, and on the economic parameters of the project. In responding to the risks, there are four general types of risk response: risk avoidance or reduction, risk transfer and risk retention. The approach proposed by the standard model is very flexible because it gives the user the freedom to choose techniques that are appropriate for a particular project, industry and level of detail (Smith, 1999).

A project is divided into a number of separate phases. At the end of each phase an appraisal can be made and assessment of the risks involved can be documented and communicated to members of project teams involved in subsequent phases of the project. The management of risk is therefore a continuous process and should span all the phases of the project. Since project risks are dynamic, that is to say that they can change continuously, a risk assessment must be carried out at the end of each phase prior to proceeding to the next phase (Smith, 1999). Typically, as a project proceeds through its life cycle, the more accurate and reliable risk management becomes. In other words, the level of uncertainty and ambiguity begins to decline (Kliem, 1997). During the appraisal phase there are a large number of risks in the project, since few decisions have been made and there is a high level of flexibility. As the project progresses more decisions are made, which should reduce the amount of risk in the project, however, this also reduces the ability to make changes to the project, and increases the cost of making these changes (Smith, 1999). Integrated risk management requires an ongoing assessment of potential risks for an organization at every level and then aggregating the results to facilitate priority setting and improved decision-making (Treasury Board of Canada, 2001).

4.7 IDENTIFY STAKEHOLDERS: Select Risk Management Team (STEP 4.1)

4.7.1 Activities

The most common way to perform risk analysis is to gather key personnel for risk identification sessions, and then interview them in groups or as individuals. The intent of gathering the individuals should be clearly stated and for the singular purpose of discussing, assessing and quantifying the risks affecting project parameters (Smith, 1999).

Both the risk analyst and the individuals involved in the risk assessment process bring with them the possibility of introducing bias to the results. Bias can be minimized by awareness of the possibility of bias, adjusting the analysis process according to the number of people involved in the process and the complexity of the project, and the use of an experienced facilitator in gathering information and facilitating consensus. Smith (1999) indicates that groups are important to the process and make better decisions than individuals, and that groups create stronger ownership to risk assessments and the results from analyses (Smith, 1999). Social psychologists have put considerable effort into specifying the ideal size of a problem-solving group and conclude that: “groups of five are the most effective for dealing with mental tasks in which group members collect and exchange information and make a decision based on the evaluation of this information” (Smith, 1999). A useful and productive group will commonly have experts from various disciplines with interfaces with the topics on the agenda. This will lead to fruitful discussions and communications across the project organization (Smith, 1999). Such a group process stimulates participants to communicate and express their opinions in an open minded environment where people are free to express whatever concerns they have (Smith, 1999).

4.7.2 Stakeholders

Stakeholder identification,—identifying people or groups who influence the project progress or its outcome—is crucial. It begins the process of finding information about the potential contribution to risks during and beyond the project's lifecycle and it is the first step in dealing with human factors in risk management. Key information will be gained about the stakeholder's abilities, perceptions, values and motivation (Merna, 2005). Upon the identification of the stakeholders involved in the project, a project risk assessment team can be organized.

4.7.3 Risk Management Team

Project risk assessment teams can serve the organization in a number of different ways (Merna, 2005):

- By conducting competent risk assessments for every project;
- By developing a process for risk assessment including standards and procedures for the organization;

- By serving a mentoring and consulting role for players in the organization who need guidance on appropriate risk assessment practices;
- By offering risk management training, both formally and informally;
- By selecting and maintaining risk management tools and techniques; and
- By serving as the central repository for the distribution of risk management resources to the organization,

4.7.4 Risk Manager

Just as the overall project requires a manger, a risk facilitator or manager is necessary for each individual phase of the project. Desirable attributes for the phase manager will be similar to those of the overall team manager (assessment, communications, motivation, facilitation, project management). Depending on the size and complexity of the project the position may be separate or may be an additional duty assigned to the overall project risk manager depending on the established corporate policy.

4.8 IDENTIFY RISKS (STEP 4.2)

Although project risks can be categorized in many ways, four primary groupings are presented here: physical, capability, economic, and political/societal. In the risk identification process, each stakeholder in the project will identify risks specific to their area of expertise and of which they are best able to manage (or transfer as applicable) (Fisk, 2006). In reference to the project objectives, potential risks can be identified by the various stakeholders. Risks can be identified by different perspectives—examination of the source of the risk, probable threatening scenarios or examination of the threat to the organization or project objective.

- **Source analysis** - Analyzing the source of the risk involves asking "Who or what might cause a threat to the project?" Examples of risk sources are: the traveling public, workers, the weather, project design, or traffic control.
- **Problem analysis -** Analyzing possible problems or threats to the project or the organizational objectives involves asking the question, "What problems or threats might arise?" This can be based on the organization's risk management policy statement as out lined in a previous section (goals, priorities, and risk tolerance). These risks are related to the identified threats. For example: speeding, inattentive driving, lack of safety equipment/training, slippery road conditions, congestion, obscured or inadequate signage.
- **Objectives-based risk identification—**since part of the integrated risk management program is to develop and obtain the project definition which is used to share project information pertaining to scope, objectives, and strategy of the project, any event that may endanger the project's ability to meet its objectives should be identified as a risk.
- **Scenario-based risk identification—**in scenario based identification, the risk management team is concerned with the identification of scenarios, sequences of events, and cause and effect relationships. This approach asks the, "what if?" questions associated with the project.

When either a threat or a source is identified, the events that a source may trigger or the events that can lead to a problem can be investigated. For example: the threat of the traveling public speeding through the work zone should prompt an inquiry from the risk management team.

Numerous techniques can be applied by the risk management team for the identification of project related risks. The following sections list some of these methods.

4.8.1 Brainstorming Sessions

Indentifying risks can often be accomplished by establishing brainstorming sessions which involve getting the key project personnel together to identify and prioritize the risks in the project. This technique enables the project personnel to hear what the other members of the project team see as risks and then to use these ideas to give themselves inspiration in identifying additional project risks. It is important to choose carefully the people who are to make up the brainstorming group—it is essential to include the right mix of project personnel with appropriate experience and seniority to ensure a successful session (Smith, 1999).

The optimum size for a brainstorming session is twelve people and the ideal length of time is between fifteen and 45 minutes. Some basic ground rules surrounding the brain storming session need to be established (Merna, 2005):

- impose a time limit;
- provide a clear statement of the problem;
- develop a method of capturing ideas (white board, flipchart, etc);
- determine a visible location to leave the ideas to let them incubate;

- foster the principle that no idea is a bad idea;
- encourage participants to be creative and wonder around the topic;
- encourage quantity not quality (evaluations can come later); and
- develop group ideas.

4.8.2 Interviews

In addition, interviews provide a means of soliciting information from individuals. Project personnel can be asked to provide information regarding potential risks at the project level (Merna, 2005). Interviewing project personnel from each discipline and staff within the organization who have experience on similar projects ensures that organizational knowledge and personal experiences are utilized in the process of identifying risks. This allows project personnel to have a say in risk identification and gives them a sense of involvement and ownership in the process. This will also make them more receptive to implementing recommended risk reduction measures (Smith, 1999).

4.8.3 Historic Data

Data collected from previous projects may be utilized to identify possible risks, however this is only viable when there is similarity in projects and there has been some record keeping (Smith, 1999).

4.8.4 Check lists

Using checklists is another way to document sources of risk or risk drivers. Many projects are different in many ways however the key sources of project risk are often quite similar among projects. The sources of the risk are generic so it is up to the project team to define the boundaries of the sources and break down the sources into detailed risk elements (Smith, 1999). Development of checklist templates is one of the primary outcomes of this research.

Typical construction risk drivers include (Smith, 1999):

- financial risks,
- legal risks,
- political risks,
- social risks,
- environmental risks,
- communications risks,
- geographical risks,
- construction risks,
- technological risks, and
- demand/product risks,

Checklists are deductive techniques derived from risks encountered previously and provide a convenient means for management to rapidly identify possible risks. They take the form of either a series if questions or a list of topics to be considered (Merna, 2005).

4.8.5 Prompt lists

Prompt lists are used to stimulate open discussion. This deductive technique presents topics, or prompts, as means for facilitating the classification of risks into type or area groups (financial, technical, environmental), or task groups (planning, design, construction, commissioning) (Merna, 2005).

4.8.6 Risk Charting

Risk charting is a process of creating a graphical representation or matrix which represents the resources at risk and the threats and consequences associated with them. To begin with, the search for risk must be reduced to its simplest terms and the single question that must be asked is: "What can go wrong?" (Crockford, 1986). Once lists of risks have been completed it is possible to arrange the various items in the different columns alongside one another and consider how they interrelate. One can consider the resources in turn and relate each threat to them, or one can start with each threat and consider which of the resources come within its range and which of the modifying factors increase or decrease the risk (Crockford 1986). This method is capable of producing either a very broad or very detailed pictures of risk, according to what is needed, but it has to be based upon on an "on the spot" examination of operations (Crockford 1986). The picture of risk identified varies according to the accuracy of the examination and knowledge of the situation. In risk identification, there is no substitute for going out to see what is done, how it is done, where it is done, by whom it is done by and what is used to do it, or for asking questions of the people involved in the day to day operations, who are often the only people who know what goes on in fact, as distinct from what is presumed to go on (Crockford, 1986).

4.8.7 Grouping Risks

Grouping risks is one method used to ensure that risks are accurately and fully identified and are managed under the best authority and mitigation strategy. Although construction risks can be categorized in many ways, four common groupings are: physical, capability, economic, and political/societal. In the process of identifying risks, those that are created by the parties themselves in their attempts to transfer the risks are included (Fisk, 2006).

4.9 ASSESS RISKS (STEP 4.3)

After risks are identified, they must be assessed according to their potential severity of loss and probability of occurrence. This must be done within the constraints of the organizational and project objectives and risk tolerance criteria. These assessments should be based on educated estimations as the probability of an unlikely event occurring or the impact of a loss associated with a nonmaterial asset may be difficult to determine. However, the assessment process is critical in order to prioritize the implementation of the risk management program. Often educated opinions and available statistics are the primary sources of information in the assessment of risk. Risk quantification and analysis involves risk and risk interactions to assess the range of possible outcomes. It is primarily concerned with determining which risk event warrants a response (Merna, 2005).

4.9.1 Qualitative risk analysis

Qualitative risk analysis consists of compiling a list of risks and a description of their likely outcomes. Qualitative risk analysis involves evaluations that do not result in numerical value. Instead this analysis describes the nature of the risk and helps to improve the understanding of the risk. In this way analysts are able to concentrate their time and efforts on areas that are most sensitive to the risk. Quantitative risk analysis often involves the use of computer models employing statistical data to conduct risk analysis (Merna, 2005).

A typical qualitative risk assessment for construction projects usually includes the following issues: brief description of the risk; stages of the project where it may occur; elements of the project that could be affected; factors that influence occurrence; relationships with other risks; likelihood of it occurring; and how it could affect the project (Smith, 1999). Failure to think through the needs and risks associated with a project may cause problems through contract strategy that may not provide an equitable allocation of risks identified.

4.9.2 Assumptions analysis

Assumptions analysis is an intuitive technique where assumptions typically made in project planning are identified. They are then assessed as to what impact their proving false will have on the project outcome (Merna, 2005).

4.9.3 Delphi

This is a technique for predicting a future event or outcome in which a group of experts are asked to make their forecasts, initially independently and subsequently by consensus in order to discard any extreme views (Merna, 2005). The process as described by Merna (2005) in this way: “respondents are asked to give their opinion on the risks pertaining to a project; a chairperson collects the information and issues a summary of the findings to the respondents requesting that they revise their opinion in light of the group’s collective opinion; these steps are repeated until either consensus is reached or the chairperson feels that no benefit will result from further repetitions” (Merna, 2005).

The classic delphi method is modified to fill the needs of particular projects. Experts give their opinion as to the probability of occurrence and possible impact of the risk on the project should it occur. In this method the consensus is not gained through survey. Experts are brought together in the form of a meeting presided over by a moderator. This group of experts must be comprised of an inter-disciplinary team in order to minimize the effects of bias within the group (Smith, 1999).

4.9.4 Risk Mapping

Risk mapping involves the graphical representation of risks on a two-dimensional graph where one axis relates to the potential severity of a risk eventuating and the other to the probability of doing so (Merna, 2005).

4.9.5 Risk Matrix

A risk matrix determines the levels of each identified risk by combining the probability of occurrence of the risk with the impact of the risk on the project. Probability and impact can both be measured on a continuum ranging from low, medium, to high. The matrix is generated by the qualitative assessment provided by a number of people using the identified variables. Using this method aids in identifying which risks have the least bearing on the project and which need further investigation (Smith 1999).

4.10 RISK TREATMENT (STEP 4.4)

Once risks have been identified and assessed, risk treatment can be applied. Risk treatment is the process of selecting and implementing measures to modify the risk. Risk treatment includes as its major element risk control/mitigation, but extends further to (AIRMIC, 2002):

- avoidance (elimination);
- reduction (mitigation);
- retention (acceptance and budgeting); or
- transfer (insurance or hedging).

The goals and missions of an organization should be considered when selecting a risk management strategy. It may not be practical to address all risks and options may involve trade-offs that are not acceptable to the organization or person making the risk management decisions. Thus prioritization is important (Stoneburner, 2002).

4.10.1 Risk avoidance

Avoiding a risk involves not performing any task which could have a risk associated with it. An example of this might involve the decision to provide an off-site detour in order to avoid the risks associated with building under traffic conditions. It could involve choosing not to undertake a particular project. Avoidance may seem the desired answer to risk management, however avoiding risk may mean losing out on gain or opportunity that accepting (retaining) the risk may allow.

4.10.2 Risk reduction

Reduction of a risk means acknowledging the potential of a risk occurring and taking appropriate steps to prevent the risk from triggering. Another way to mitigate a risk is to put in place a contingency plan or procedure to deal with the risk if it occurs. Examples of these types of measures on a roadway project might include the reduction of traffic speed by positive traffic control and law enforcement or the wearing of high visibility apparel by workers.

4.10.3 Risk retention

Risk retention involves the acceptance of the idea that a loss may occur and being prepared to deal with it if it should occur. Risk retention is usually a viable option for small risks associated with a project. Budgeting through contingency funds is one way of accepting the risk. An example of risk retention in a project includes budgeting for the replacement of traffic control devices which are damaged during construction. However, a risk may also be accepted during a certain phase of a project (i.e. planning or design phase) with the intention of mitigating the risk in a subsequent phase (i.e. construction). An example of this type of risk acceptance would be the acceptance of geometric constraints on the project during the design phase with the intention of mitigating this risk during construction with the use of traffic control devices or flaggers.

4.10.4 Risk transfer

Risk transfer means causing a third party to accept the risk, typically by contract, insurance or by hedging. In risk transfer, the risk doesn't go away, however an outside source or team is delegated to handle the risk. Examples of risk transfer include the use of contractual documents and by employing co-op purchasing agreements or other account agreements.

4.11 RECORD/DOCUMENT PROJECT RISK INFORMATION (STEP 5)

The documentation of project risks, responses and responsible parties is an ongoing process that captures the data from one project and can be carried over into the next. In the form of a risk register or a risk log, this tool can be used in much the same way as a checklist or identification aid in successive similar projects. The risk register doesn't solve risks, but helps to identify the responsible party (Merna, 2005). Interviews, reviews of the program, and budgets should form the basis or the listing of all identified risks in the risk register or risk log (Smith, 1999). Recording and sorting risk information according to headings such as project phase, holder of risk, location, or others can permit for a qualitative assessment (high, medium, low) of the risk and permits quantitative and quasi-quantitative analysis based on percentage probability and cost impacts (Smith, 1999). The risk log can be updated continuously and contains valuable information on actions to avoid, transfer or mitigate (Smith, 1999).

4.12 EVALUATE PROJECT RISK MANAGEMENT PROGRAM (STEP 6)

In order for a risk management plan to be effective, the process must be evaluated to determine if the risks were properly identified and assessed and that appropriate controls and responses were put in place. This process will aid in the identification of opportunities for improvement. Also any changes in personnel within the project and organizational changes will need to be identified in order for appropriate modifications to be implemented. The evaluation process should determine if (AIRMIC, 2002):

- the adopted measures performed as intended;

- the specified procedures and information gathering activities were appropriate; and
- knowledge gleaned from the process and lessons learned will be beneficial in future applications.

4.13 CHAPTER SUMMARY

The proposed template detailed in this chapter supplies the framework which much be in place within an organization in order to apply the integrated risk management program and processes. The model developed in this chapter details the required steps which must be undertaken in such an endeavor: obtaining a risk management policy statement, assigning risk management responsibility, developing a project definition, applying the standard risk model (identify risks, assess risks, treat risks), documenting project risk information, and evaluating the program. The remainder of this dissertation will focus on the validation and application of the process through a detailed examination of the standard risk model step (Step 4) of the process.

CHAPTER 5

RESULTS

5.1 INTRODUCTION

The purpose of this section is to utilize the methods described in the risk management model development process (Chapter 4) to identify, assess, and respond to specific risks, in particular the risk of vehicle crashes and fatalities in roadway work zones. Essentially, the scope of this research is to create a list of work zone hazards that can be identified during each stage of the project development process for a typical roadway project. Ultimately, the results of this section will provide a list of identified hazards for each stage of the project development process; develop a method to assess hazards utilizing crash data provided from the Iowa Department of Transportation; and will provide a list of possible mitigation strategies for each of the identified hazards that may be implemented in each phase of the project development process. The results of this section are not intended to represent a specific roadway project; the intent is to utilize the standard risk management model for a typical highway project. In addition, this project and the processes and methodologies used focus on a single risk—vehicle crashes involving the traveling public in a work zone environment. Numerous other risks (i.e. work site safety not involving the traveling public, financial loses, and such) may be associated with transportation projects and can be managed in the same manner; however management of those risks remains outside the scope of this research. Thus the following results utilize processes to identify hazards which increase the frequency and severity of vehicle crashes involving the traveling public in roadway construction work zones.

5.2 RISK IDENTIFICATION TECHNIQUES & METHODS

In the risk identification section of the risk management model development process discussed in Chapter 4, various risk identification techniques or methods were recommended. The process used for risk identification is summarized in the following outline:

1. Brainstorming –
   a. Source analysis—involves examination of the project to determine hazards which may originate from the following
      i. Five Factors of Work Zone Crashes
      ii. Primary Causes of Work Zone Crashes
   b. Problem analysis based on the department risk management policy statement (Step 1 of the Integrated Risk Management Program)
   c. Objectives based risk identification based on the specific project definition (Step 3 of the Integrated Risk Management Program)
   d. Scenario based risk identification generated from risk grouping & risk mapping/charting, and also developed by the integration of cause & effect relationships, and the sequence of events between a loss and a hazard.
      i. Hazard
      ii. Primary Cause (compare w/Proximate Cause)
      iii. Possible Outcome (compare w/ peril)

iv. Possible Loss (compare w/ loss)

2. Historic Records based on literature search/review and work zone crash data
3. Interviews with expert panels and focus group discussions
4. Checklists/prompt lists to serve as prompts for common risk checking
5. Delphi Technique to consolidate and prioritize risks and hazard

Source Analysis (1a.i and 1a.ii), Scenario based analysis (1d.i-1d.iv) and Checklists (4) were uniquely developed as part of this research. Other aspects of risk identification have been adopted from prior research and standard risk management models.

The fundamental objective of risk management in this project is to identify risks that are associated with highway work zones—in particular, losses associated with vehicle crashes in order that a process may be developed to mitigate the risk. It is necessary at this juncture to emphasize that there are many risks associated with highway road projects: financial, political, economic, safety, theft, etc. Although the risk management model developed in Chapter 4 is very generic and can be applied to all highway projects this research is concerned with mitigating work zone crashes and fatalities. Therefore, the risk management model will be explicitly applied with a focus on work zone accidents that are caused by the interaction of the work zone conditions and the traveling public. This is accomplished by focusing on the hazards that by definition are circumstances that increase either the frequency or severity of a loss. To assist with the initial steps associated with the identification of risks, Table 5.2.1 was created in order to provide a list of the possible outcomes (cause of loss) that are directly related to the risk of loss associated with vehicle crashes in a roadway work zone. These “possible outcomes” have been tabulated to assist in the identification of work zone hazards that may lead to losses associated with work zone accidents.

Table 5.2.1: Possible Outcomes associated with the risk of work zone vehicle crashes

POSSIBLE OUTCOME	OUTCOME REASON
• Worker struck by motorist	• Motorist intrudes work space • Worker in traffic space
• Const. Equipment struck by motorist	• Motorist intrudes work space • Equipment intrudes traffic space
• Facility/structure struck by motorist	• Motorist intrudes work space
• Motorist struck by: o Const. equipment o Const. vehicle o Const. debris/materials	• Motorist intrudes work space • Construction Equipment, vehicles, or debris intrudes traffic space
• Motorist struck by motorist(s)	
• Motorist roll-over	
• Pedestrian struck by: o Const. equipment o Const. vehicle o Const. debris/materials	• Pedestrian intrudes work space • Debris or construction equipment or vehicles intrude into designated walking space
• Pedestrian struck by motorist	

5.2.1 Content Analysis Results (Prompt list/Checklist)

The starting point of this research was the creation of a checklist or prompt list that was used to stimulate ideas or thoughts about the risks associated with highway work zones. This check list was created using content analysis of research papers, journal articles, and various Department of Transportation memoranda. Articles and papers were identified based on their direct applicability to work zones and the management of risks associated with vehicle crashes and fatalities. Ultimately a list of hazards was created using multiple sources. Each hazard, along with the corresponding author is listed in Tables 5.3.1 – 5.3.5. Many of the hazards were repeated several times and the variations of the hazard were included to show the perspective of the particular author/researcher. Table 5.3.1 through Table 5.3.5 provides the results of the content analysis as grouped through the qualitative analysis described in the subsequent sections. The purpose of the checklist was to serve as a starting point for the research, facilitating the development of a risk identification and response (treatment) template to be utilized during the focus group discussion.

5.2.2 Source Analysis (Risk Grouping)

Since risk sources can be internal or external to the system that is being managed for risk, source analysis can be done by grouping hazards into specific areas (i.e. characteristic of the roadway, environmental conditions, driver characteristics, vehicle characteristics, and such). Risk grouping serves several purposes. First, it allows the risk management team to compartmentalize the risks into areas of responsibility, ensuring that the risk is managed by the entity that is in the best position to control or mitigate the risk. Secondly, the groupings allow the researchers and risk management teams to assess the hazards with crash data provided by state highway agencies. In the case of this research, the groupings or factors were beneficial in determining which database fields needed be explored in order to design queries to extract crash data from the highway crash database. (Refer to the risk assessment portion of this chapter).

Five Factors of Work Zone Crashes

A review of literature relating to hazards identified as contributing causes to highway/roadway crashes and fatalities resulted in an exhaustive list of hazards which were subsequently categorized into "factors" that affect crashes. Although this list may not be all inclusive, the intent of the categorization is to determine a list of the factors that can effectively be addressed/managed during the construction management and administration process of each stage of the construction project lifecycle.

During the content analysis stage of this research, five factors or groups emerged as having the primary influence on work zone crashes and fatalities:

1) driver characteristics,
2) operating environment,
3) road characteristics,
4) vehicle characteristics, and
5) work zone conditions.

Primary Causes of Work Zone Crashes

In addition to the five factors associated with work zone crashes, it was found upon further analysis of the list of hazards that in general, crashes are caused when motorists lose control (either physically or emotionally), lose visibility, or become confused. Therefore, it is through the lens of these three primary causes of work zone crashes that identifying risks during all stages of the project life cycle can best be utilized. Policy makers, managers, planners, designers, and constructors can identify potential hazards while assessing plans, designs, and jobsites by asking three questions:

(1) When and where could the motorist lose control?

(2) When and where could the motorist lose visibility?

(3) When and where could a motorist become confused?

The concept of primary causes proved to be very helpful in the development of the taxonomy method of risk identification which utilizes the causal relationship between a hazard and a loss. This concept has also provided benefit to the risk charting and mapping tool that was developed in order to facilitate the scenario based risk identification method and has become one of the major contributions of this research.

A systematic procedure devised to examine the content of recorded information, namely a content analysis (Winner, 2006) was applied to various work zone related literatures in order to compile lists of work zone hazards. The results of the content analysis are displayed in Table 5.3.1 through Table 5.3.5 which are presented by each of the five factors of work zone crashes. Each of the five tables also label hazards in terms of primary causes and includes the literary source. Table 5.3.1 contains the work zones hazards as grouped by driver characteristics, Table 5.3.2 contains the work zones hazards as grouped by operating environment, Table 5.3.3 contains the work zones hazards as grouped by road characteristics, Table 5.3.4 contains the work zones hazards as grouped by vehicle characteristics, and Table 5.3.5 contains the work zones hazards as grouped by work zone condition.

Table 5.3.1: Work Zone Hazards grouped by Driver Characteristics – from various sources

DRIVER CHARTERISTICS		
HAZARD	**PRIMARY CAUSE**	**SOURCE**
Aggressive driving	Loss of control	Roadway Safety Foundation - 2007
alcohol impairment	Loss of control	Ha and Nemeth - 1995 (ODOT)
alcohol impairment	Loss of control	Garber and Woo - 1990 (University of Virginia)
alcohol/drug impaired drivers	Loss of control	Roadway Safety Foundation - 2007
alcohol/Drug influence	Loss of control	Dissanayake and Lu - 2002 (University of South Florida)
bad driving situations	Loss of control	Benekohal et al. 1995 (IDOT)
following too close	Loss of control	Chambless et al. - 2002
following too close	Loss of control	Pigman and Agent - 1990 (University of Kentucky)
following too close	Loss of control	Hall and Lorenze - 1989 (NMSTHD & FHWA)
high speed	Loss of control	Pratt – 2001
high speed vehicle does not slow in work zone	Loss of control	Hausman – 2007
high speed vehicle encounters stopped traffic	Loss of control	Hausman – 2007
inattentive driving	Loss of control	Iowa DOT 1999
lack of information	Confusion	Iowa Department of Public Safety - 2007
misjudge stopping distance	Loss of control	Chambless et al. - 2002
sex of driver		Texas Tech (Hill et al. - 2003)
sex of driver		Dissanayake and Lu - 2002 (University of South Florida)
speed (excess travel speed)	Loss of control	Dissanayake and Lu - 2002 (University of South Florida)
speed of crash vehicle	Loss of control	Dissanayake and Lu - 2002 (University of South Florida)
Speeding	Loss of control	Iowa DOT 1999
unbelted - ejection in the crash	Loss of control	Dissanayake and Lu - 2002 (University of South Florida)
Unbelted motorist	None	Roadway Safety Foundation - 2007
Youth and Young adults	Confusion	Roadway Safety Foundation - 2007

Table 5.3.2: Work Zone Hazards grouped by Operating Environment – from various sources

OPERATING ENVIRONMENT		
HAZARD	**PRIMARY CAUSE**	**SOURCE**
congested area	confusion loss of control	Pratt – 2001
heavy traffic	Confusion	Hausman 2007
high traffic volume	Confusion	Pratt – 2001
low lighting	Loss of visibility	Pratt – 2001
low visibility	Loss of visibility	Pratt – 2001
pedestrians	Loss of visibility	Roadway Safety Foundation - 2007
time - day of week – Fridays	Loss of control	Hausman 2007
time of day	Loss of control	Texas Tech (Hill et al. - 2003)
time of day	Loss of control	VDOT (Garber and Zhao - 2002)
time of day (night time)	Confusion	Pigman and Agent - 1990 (University of Kentucky)
time of year - summer months	loss of control	Hausman 2007
Traffic Slow downs	loss of control	Ha and Nemeth - 1995 (ODOT)
stopping/slowing vehicles	loss of control	Mohan and Gautam - 2002
weather - inclement weather	loss of visibility loss of control	Hall and Lorenze - 1989 (NMSTHD & FHWA)
Weather - adverse weather conditions	loss of visibility loss of control	Garber and Woo - 1990 (University of Virginia)
weather - inclement weather	loss of control loss of visibility	Pratt – 2001

Table 5.3.3: Work Zone Hazards grouped by Road Characteristics – from various sources

ROAD CHARACTERISTICS		
HAZARD	**PRIMARY CAUSE**	**SOURCE**
road condition (bad roadway surface)	loss of control	Hall and Lorenze - 1989 (NMSTHD & FHWA)
road condition (edge drop / soft shoulder)	loss of control	Ha and Nemeth - 1995 (ODOT)
road geometry (at-grade)	loss of control confusion	Dissanayake and Lu - 2002 (University of South Florida)
road geometry (curves)	loss of control loss of visibility	Dissanayake and Lu - 2002 (University of South Florida)
road type	loss of control	VDOT (Garber and Zhao - 2002)
road type (interstate)	loss of control	Pigman and Agent - 1990 (University of Kentucky)
road type (interstate, etc)	loss of control	Chambless et al. - 2002
roadway type - crash location (rural)	loss of control	Dissanayake and Lu - 2002 (University of South Florida)

Table 5.3.4: Work Zone Hazards grouped by Vehicle Characteristics – from various sources

VEHICLE CHARACTERISTICS		
HAZARD	**PRIMARY CAUSE**	**SOURCE**
large trucks	Confusion	Hausman - 2007
trucks (at crossovers)	loss of control confusion	Ha and Nemeth - 1995 (ODOT)
Type of vehicle - trucks	Confusion	Pigman and Agent - 1990 (University of Kentucky)
type of vehicle (commercial, non-commercial)	loss of control	Texas Tech (Hill et al. - 2003)

Table 5.3.5: Work Zone Hazards grouped by Work Zone Condition – from various sources

WORK ZONE CONDITION		
HAZARD	**PRIMARY CAUSE**	**SOURCE**
Construction Vehicle Traffic	confusion loss of control	Pratt - 2001
construction workers	loss of visibility loss of control	Mohan and Gautam - 2002
guardrails	loss of control	Ha and Nemeth - 1995 (ODOT)
improper traffic control	Confusion	Hall and Lorenze - 1989 (NMSTHD & FHWA)
improper traffic controls	Confusion	Ha and Nemeth - 1995 (ODOT)
inadequate/confusing traffic control	Confusion	Ha and Nemeth - 1995 (ODOT)
ineffective speed reduction attempts	loss of control	Ha and Nemeth - 1995 (ODOT)
Lane Changing/merging	Confusion	Ha and Nemeth - 1995 (ODOT)
lane Closure - Congestion	loss of control	Znamenacek - 2005
speed - posted speed limit	loss of control	Chambless et al. - 2002
workers - construction workers	loss of visibility	Mohan and Gautam - 2002
WZ length - long work zones	loss of control	Garber and Woo - 1990 (University of Virginia)
WZ length - length of work zone	loss of control	Garber and Patel - 1994 (VRTC & VDOT)
WZ location - termination area - fewest # crashes	Confusion	VDOT (Garber and Zhao - 2002)
WZ Location (transition/activity/termination)	Confusion	VDOT (Garber and Zhao - 2002)
WZ Location -activity area – highest # crashes	loss of control	VDOT (Garber and Zhao - 2002)

5.2.3 Scenario Based Identification (Risk Charting/Mapping):

One of the primary contributions of this research is the development of a risk identification tool to be utilized by the risk management team for the mitigation of work zone crashes and fatalities. As mentioned in the previous chapters, risk charting is a method of determining "what can go wrong?" (Crockford, 1986). In the utilization of this process; threats, resources, modifying factors, and the consequences are "charted" in order to help identify hazards associated with potential losses. However, in order to determine what can go wrong it is necessary to understand the causal relationship between a hazard and a potential loss. This is accomplished by utilizing a form of the taxonomy approach of risk identification that relies on subtype and supertype relationships, a causal relationship between the hazard and loss is determined by first reviewing and understanding the methods utilized in the insurance and finance industries to manage risks.

It is reasonably understood that the primary "risk" associated with highway/roadway work zones is vehicle crashes. The "loss" associated with a vehicle crash is typically defined within a range of severities – fatality, injury or property damage only (PDO). The insurance industry defines "loss" as an undesired, unplanned reduction of economic value (delay, property damage, disability, death), while a "hazard" is defined as a circumstance which increases either the frequency or severity of a loss (bad character, weather conditions, faulty equipment) (Dorfman, 2005). A "peril" is defined as the cause of the loss (fire, automobile crash, hurricane, etc.) and the "proximate cause" is defined as the initial act which sets off a sequence of events that produce the loss (Dorfman, 2005). Therefore, the concept of "proximate cause" as a method for identifying hazards will yield important information concerning the conditions and causes contributing to work zone crashes.

The idea of "proximate cause" originated from a legal exposte analysis of the peril that caused a loss to occur. The purpose for explaining the concept of proximate cause is to show that there is a cause-and-effect relationship between hazard, peril, and loss. Although, proximate cause assumes a degree of negligence, the concept of an initial act that sets off a string of events that leads to loss is especially useful in risk mapping and ultimately risk management when the concept is applied ex ante. This relationship will form the basis for the risk management approach of this research. Figure 5.4.1 shows a graphical representation of the causal relationship between a hazard and a loss.

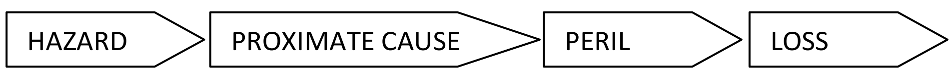


Figure 5.4.1: Graphical representation of causation between hazard and loss

The insurance industry typically utilizes this process to assign responsibility or blame for the cause of a loss – ultimately, the process is exposte, or after the fact. This research has modified this process by a making the process more proactive or ex ante'. The tool that emerged from this process is the development of a risk mapping process. This risk mapping approach was developed specifically for the identification of hazards in work zones by working backward from the possible loss to the determination of the "first step" in a chain of events that result in a loss. Figure 5.4.2 shows the graphical representation of the process that was developed as a result of this research project.

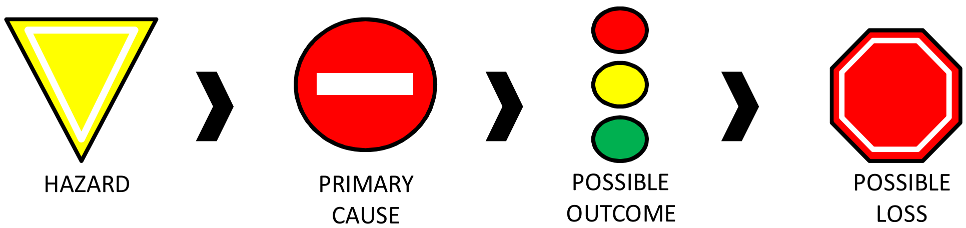


Figure 5.4.2: Graphical representation of Work zone Hazard Analysis Process (ex ante')

As stated in the previous sections, the purpose of this model is to work backwards from the possible loss in order to determine the factors and conditions that cause a loss to occur. In general, the "possible loss" is an unplanned, undesired loss of economic value—particularly, death, injury, or property damage. Many other losses such as the cost of delay can be considered in this model but the scope of this research has been limited to the confines of vehicle crashes and fatalities. Figure 5.4.3 shows the possible losses as considered in the scope of this research.

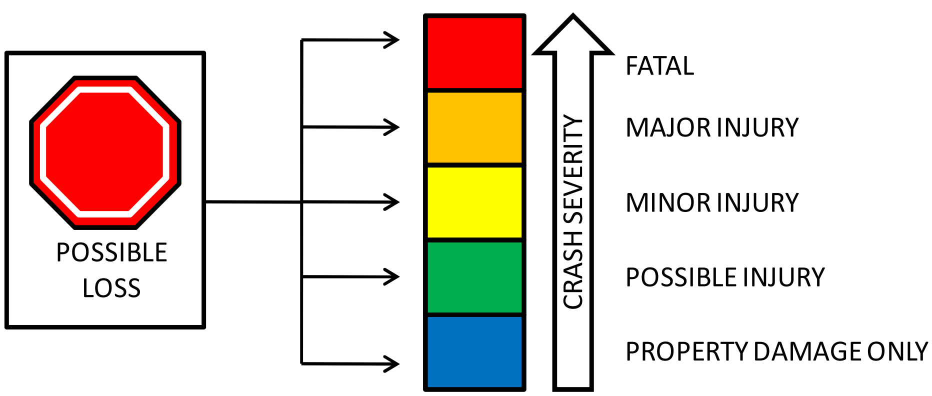


Figure 5.4.3: Possible Loss associated with Vehicle Crashes in Work Zones

For this research, the "possible outcome" is similar to the peril (cause of loss) because the interaction between the driver and the work zone factors and conditions is the recipe for a loss to occur. This is because the loss would not be realized if a driver/operator was not involved in a collision with another entity. Figure 5.4.4 graphically represents a portion of the possible outcomes that may occur as a result of a work zone vehicle crash as listed in Table 5.2.1 in an earlier section.

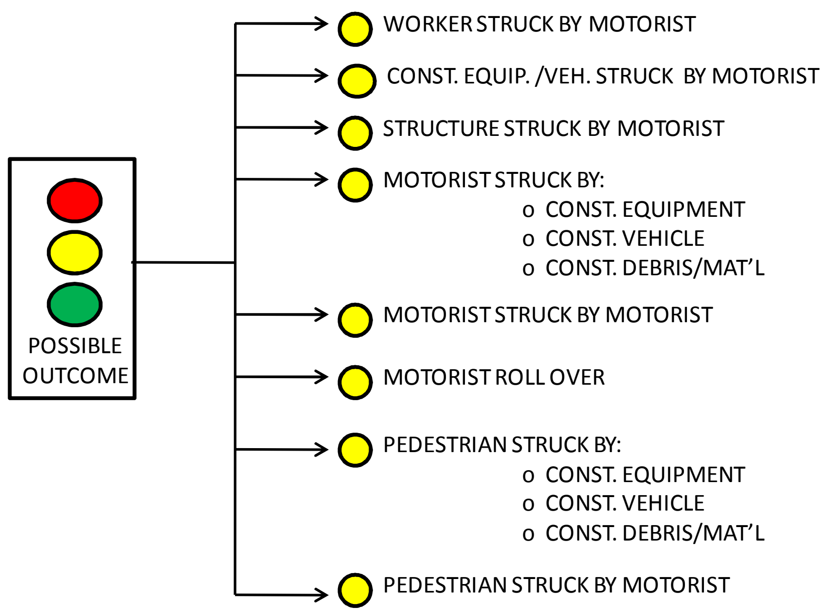


Figure 5.4.4: Possible Outcomes Associated with Vehicle Crashes in Work Zones

In the insurance industry the terminology, "proximate cause of a loss" relates to the first peril in a chain of events resulting in loss. It is the first step without which the loss would not have occurred (Dorfman, 2005). Since the term "proximate cause" is a legal term that generally infers negligence, "primary cause" has been adopted in this research as term that reflects the ex ante meaning of the exposte "proximate cause". Figure 5.4.5 shows a graphical representation of the primary causes of work zone vehicle crashes.

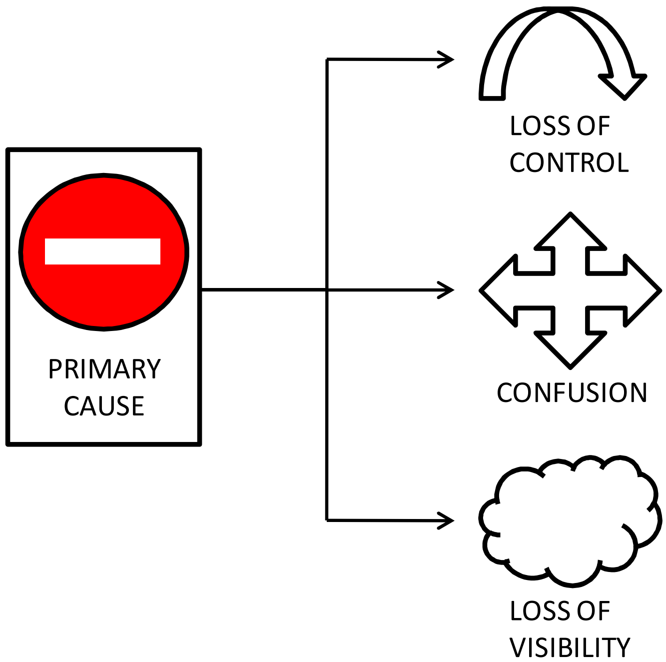


Figure 5.4.5: Primary Cause of Vehicle Crashes in Work Zones

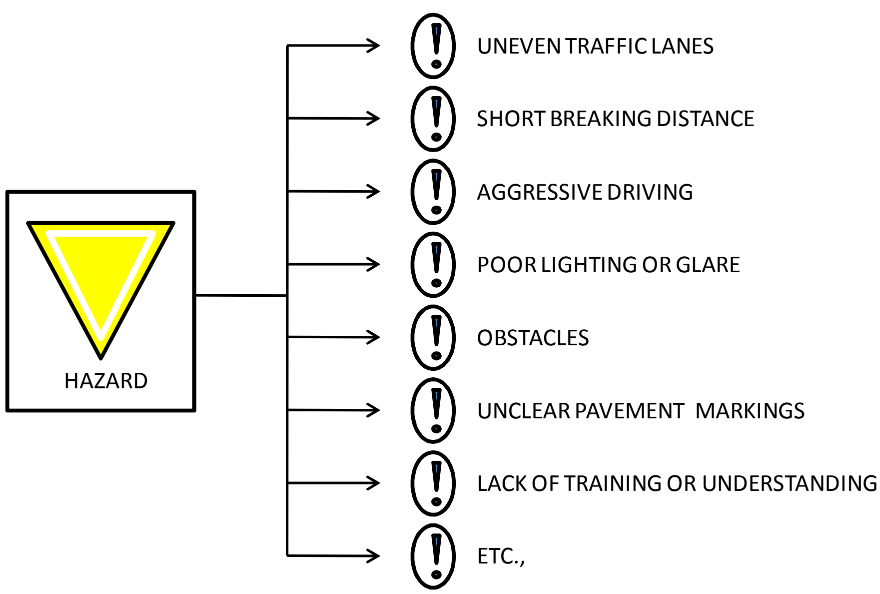


Figure 5.4.6: Typical Hazards associated with Vehicle Crashes within Work Zones

Table 5.4.1: Relationship between "Primary Cause" and Contributing Hazard (exante')

PRIMARY CAUSE	CONTRIBUTING HAZARD

LOSS OF CONTROL	• INATTENTIVE DRIVING
	• AGGRESSIVE DRIVIING
	    • TRAFFIC DELAYS
	    • TRAFFIC SLOW DOWN
	• DISTRACTIONS
	• HASTE (POOR JUDGEMENT)
	• SURPRISE
	    • REACTION TIME
	    • BRAKING DISTANCE
	• SPEED/SPEEDING
	    • REACTION TIME
	    • BRAKING DISTANCE
	• ROAD CONDITIONS
	    • ROAD GEOMETRY
	    • SLOPES
	    • POTHOLES
	    • UNEVEN LANES
	    • SHOULDERS MISSING/DAMAGED
	    • WEATHER (SNOW, ICE, RAIN)

CONFUSION	• SIGNS • BARRIERS • PAVEMENT MARKINGS • JOBSITE CONGESTION • TRAFFIC DENSITY • CONSTRUCTION ACTIVITY/DENSITY • LACK OF TRAINING/UNDERSTANDING • TRAFFIC PATTERNS
LOSS OF VISIBILITY	• LIGHTING (POOR) • GLARE • WORKER & EQUIPMENT BLEND IN TO SURROUNDINGS • INCLEMENT WEATHER • OBSTACLES (POOR LINE OF SIGHT) • BLIND INTERSECTIONS • BLIND CURVES (HORIZ. & VERT.)

Figure 5.4.6 shows a graphical representation of several hazards that are associated with work zone crashes and fatalities. Hazards are conditions that increase the frequency or severity of losses (Dorfman, 2005). Therefore, hazards create the conditions to which a "primary cause" can occur (Table 5.4.5). These hazards occur physically during the construction phase of a roadway project; however, they can be identified in all phases of the project life cycle. For each construction project, based on the program/project definition and specific activities performed during a specific phase, all hazards can be identified using the

methods presented in the integrated risk management development program. Table 5.4.1 shows the general relationship between the primary cause and the contributing hazard.

5.2.4 Focus Group Objectives:

Risk Identification during Each Project Phase

This section was developed in order to identify the project phase in which a work zone hazard can first be identified, assessed, and treated. This was accomplished through the use of a focus group and was validated by an internet survey. Prior to conducting the focus group discussion, a preliminary template was created for each project phase that identified activities performed in each phase, a tentative list of stakeholders or participants in each phase, a partial list of hazards that can be identified in each phase (this utilized the results of the content analysis), and a partial list (checklist/prompt list) of mitigation strategies for each phase. A group of industry experts was selected to participate in the focus group discussion that was lead by the primary investigator of this research. The focus group was given the following objectives:

1. Create the framework for an integrated risk management model.
2. Identify activities, tasks and considerations associated with each stage of a typical project.
3. Identify stakeholders for each stage of a typical project.
4. Create a checklist of potential hazards/risks (related to work zone accidents) that are typically associated with each stage of the project.

5. Create a list of possible strategies to manage each of the identified hazards/risks for each stage of the construction project life cycle.

Appendix C shows the results of the expert panel discussion for each phase of the project development process. The results of the expert panel were compiled and developed into a survey format which required respondents to agree or disagree with the statements pertaining to hazard identification during each stage of the project development process (planning & programming, design, letting & award, and construction). The survey was intended to support the findings of the expert panel by asking a larger number of experts to state their opinions regarding the results of the expert panel discussions. Respondents were asked to identify their area of expertise and the online survey directed them to the portion of the survey that represented each respondent's specialty area. Respondents were allowed to participate in only that portion of the survey which coincided with their area of expertise.

The information gathered during the literature review was instrumental in detailing the activities associated with each phase of the project lifecycle or project development process. This allowed the focus group discussion to concentrate on the hazards associated with each phase while allowing limited discussion on the activities associated with each project phase and on the stakeholders for each phase. Detailed information on project phases, activities, and stakeholders is provided in Chapter 2.

5.2.5 Focus Group Findings: State of the practice and "best practices"

The findings from the focus group discussion have been provided in a narrative format for each project phase. The purpose of this format is to provide a "state of the practice" overview for the current project development process, which resembles that of an "informal" risk management process. This will allow for the transformation of an "informal" program into a "formal" risk management process. In this section the results of the focus group will be provided in terms of a narrative of the state of the practice for each project phase; the identification of the probable hazards associated with each project phase; and the mitigation strategies that may be implemented during each project phase.

The results from the focus group discussion facilitated the development of a list of hazards that are introduced to the project in specific project phases. In other words, some risks that are manifested in construction work zones are actually created or exacerbated by decisions made in the planning, design, or procurement phases. The focus group results also identified best practices for risk management and mitigation which was then used to construct the survey instrument to validate and confirm the hazards noted by the expert panel. Once validated by the survey results, the findings served as the foundation for the development of the project hazards checklist. In addition, the hazards identified by the focus group participants were correlated with fields on the crash data reports to produce quantifiable measures for the frequency and severity of crashes associated with specific hazards. The quantitative analysis of crash data served as further validation of the expert panel findings.

The following section details the focus group findings as associated with each phase of the project development process as defined by state highway agencies. While primary focus of the group was in the identification of project phase-specific activities, hazards associated with each phase, and state of the practice mitigating strategies; future areas in need of research or innovation were also discussed.

Planning and Programming Phase

The activities of the planning and programming stage can be combined in an attempt to simplify the identification of hazards and the associated mitigating strategies. According to the expert panel focus group, the planning and programming stage can involve a full corridor approach or can be associated with smaller scale projects. The intent is to use this phase to identify potential hazards regardless of the size and complexity of the project. Therefore this stage is primarily focused on what to do with the existing traffic and the additional traffic associated with lane and road closures. Ultimately, this phase consists of go or no-go decisions. The decisions made in this phase will have significant impact on the hazards associated with future project phases.

The focus group emphasized that during the planning and programming phase, decisions about traffic flow and traffic density are taken into consideration; these decisions are impacted by the size of the project, the volume of traffic, and local access needs. Therefore traffic decisions depend on region and location of the roadway project. Traffic volume studies are performed in this phase in order to determine how many lanes of traffic must remain open to traffic during construction for the given situation.

During this phase, decisions are made as to whether or not to “build under traffic”. This pertains to road construction and bridge construction/replacement that may require the need for contractors to work within traffic flow. The alternatives to building under traffic include providing a detour onsite, or providing an alternate route (detour) off site. The consensus of the focus group participants was that workers benefit most from a work area that is completely closed to traffic.

During the concept phase (planning and programming) decisions are made that may have an affect on local businesses and employers. It is in this stage that the external requirements are determined. Requirements posed by external entities such as the highways-for-life program and the needs of local businesses may necessitate the need to accelerate the construction schedule. At this stage planners should try to identify to the best of their capabilities how local needs will affect traffic. Adjustments to the construction schedule may be required based on these findings. This means that the contractor may be forbidden from working during certain events or is forced to perform on an alternative schedule (night construction, etc.). This may pose certain hazards for the work zone. For instance, when ramps are closed, access is limited, or when contractors are required to work at night, workers and the traveling public are placed at a greater risk of vehicle crashes. Therefore, for high volume- high speed projects, 23CFR630 Subpart J. “Work Zone Safety and Mobility” is often utilized by stakeholders as a current state of practice when building under traffic.

Focus group participants felt that there is a need for a more formal process of addressing work zone safety and mobility when building under traffic. This research project provides such a formal process through the design and implementation of an integrated risk management process. Ultimately, decisions made during the concept phase (planning & programming phase) about traffic routes will eventually affect the safety of workers and the traveling public. When considering a bridge construction project, the first decision made by planners is whether or not to build under traffic. This decision may require designers to phase construction that may force the traveling public into head to head traffic. However, in some cases, an option may present which will allow designers to shut down the roadway in order to complete the construction project without traffic interruptions. Other decisions made in this phase may also affect safety. For instance, in order to minimize the length of the work zone, decisions may be made to keep the roadway open to traffic by allowing work to be completed in segments and opening each segment up to traffic before merging traffic down again in the next work area. This is discussed later in this section.

In addition to decisions about building under traffic, decisions as to material type such as concrete pavement (PCC) or asphalt pavement (ACC) are also made. These decisions are not necessarily made in terms of managing construction risks (accessibility, duration, etc.); however implementing the material selection process into the risk management model allows decision makers the ability to control the project duration which takes into consideration the exposure of work zone hazards to the traveling public. The type of material such as PCC or ACC overlays or full depth replacement are generally influenced by economics, however material selection also affects traffic safety. When an overlay is effective in terms of strength and durability and it also reduces the construction duration it can be considered a mitigating strategy.

The focus group panel identified additional traffic generation that comes from events, holidays, seasonal travel/road use as a potential hazard during the planning phase. The Traffic Safety division of the Iowa DOT has identified that the season/month of year and the time of day impacts traffic safety and the probability of crashes. To mitigate this hazard, the contractor may be forbidden from working during certain events or may be required to perform work on an alternative schedule (night construction, etc.). Typically this needs be written in the contract during the final design and is re-introduced during letting to ensure that the contractor schedule is in agreement with specifications that recognize specific dates.

The members of the focus group felt that locating merge points in the construction project have a significant importance in the planning, design and construction phases. It was the opinion of the participants of the expert panel that merge points in locations between work areas can pose significant traffic difficulties. For instance, in cases where a work zone is located some distance from the next work zone, experts debated the wisdom of opening up all lanes to traffic between the zones because of the difficulty of re-channelizing traffic into the second zone. Some experts felt that it would be easier to keep the motorists channelized for a longer period. This is an interesting debate as researchers and authors have suggested that long stretches of work zone that do not appear to have any construction activity tend to become a hazard for motorists.

In the case of the construction of overhead structures and blasting, it was the view of the expert panel that it is desirable to completely close the work zone area to the traveling public through the use of detours and closures. However in some cases, construction phasing must be designed for demolition work when building under traffic. This is especially true for bridge demolition projects when the route may need to be closed for a specific duration (evenings). An example of this type of phasing was 2008 Twenty-fourth Street bridge replacement project in Council Bluffs, Iowa. Many of these decisions are typically made early in the project—specifically in the planning and programming stage.

During the panel discussion about the planning and programming phase, speed limit in the work zone was identified as a hazard for all project phases. However, since speed is a policy issue there is a need to retain flexibility throughout the project specifications in order to allow for adjustments for special conditions in the work zone. Another hazard which has recently received additional interest is the work zone hazard associated with oversized/permitted loads. These oversized loads have complicated the existing designs of work zones. For Iowa roadways, longer trailer assemblies hauling wind turbine components have become a difficulty is some work zones. The identified mitigation strategy in this case is to specify alternate routes for these permitted loads.

Contractor involvement and innovative contracting have been identified as potential mitigation strategies for work zone safety. The focus group expressed concern that, in general, the construction division is not as “involved” on larger projects as they are on smaller Iowa DOT projects. Also a contractor selection process that includes past safety performance and the inclusion of a project management personnel that is responsible for work zone safety issues were identified mitigation strategies.

The focus group also discussed intelligent transportation systems (ITS) as a mitigation strategy for work zone safety. This is accomplished by establishing an integrated work zone that addresses existing traffic conditions on a real time basis with the work zone traffic control design.

Design Phase

During the focus group discussion, the preliminary design, design development, and the final design phases were discussed separately. However, this narrative will combine the results of the expert panel in order to emphasize that many tasks and hazards may be identified throughout the design process and it may prove to be more beneficial to include all hazards pertaining to the design phase into one section. As mentioned in the literature review, typically the bulk of the traffic control design and specifications pertaining to the work zone is conducted in the final design stage; however it would prove beneficial if many of these hazards and mitigation strategies could be identified throughout the design phase, especially earlier in the design phase.

The preliminary design phase concentrates on the constructed facility. However initial constructability is also evaluated in this phase. Depending on the size and complexity of the project and the scope of work, an engineer may or may not be assigned or dedicated to a particular project, as such the decision making typically done in this phase may be of limited scope. The focus group of industry experts emphasized that one must be sure to recognize that the project development process is evolutionary, which means that decisions made upstream will affect actions downstream, and should be re-evaluated at each project phase. The challenge to this paradigm is that design details need to be made based on earlier decisions from the planning and programming phases, and this can pose certain design challenges. This justifies the need for a risk management program which operates throughout the various project phases to minimize such discrepancies.

During the final design phase the final details of the constructed facility are formalized. In this phase the alternate routes and detours are evaluated in greater detail. It makes sense that the traffic control plans are established once the permanent structure is in its final design stage. This means that the general alignment of the permanent structure has been determined and only temporary traffic measures need to be analyzed and designed.

Members of the expert panel emphasized that the process of risk management needs to look at risk throughout the whole project life cycle. For instance, a decision made early in a project about the use of an alternate route may not, in fact, turn out to be the best route. In a case such as this, mitigating strategies should be available to allow for compensating for subsequent decision making based on new information. In addition, decisions relating to traffic flow have typically been made after the general arrangement of the construction project has been determined, while focus group participants feel traffic flow issues need to be addressed earlier in the planning process. Also related to traffic flow are concerns about the direction, location, and flow of construction vehicle traffic. A risk management process which is incorporated into the entire project life cycle will address the probable location and flow of construction materials being brought to the site prior to awarding the project to a contractor. Also, being aware of hazards and mitigating strategies throughout the project lifecycle will limit the number of instances where DOT personnel will be required to adjust and mitigate an in-situ traffic problem.

The focus group identified “interaction points”—locations where construction traffic joins the proximity of regular traffic as a work zone hazard. The identification of the interaction points with the traveling public and pedestrians tend to take place in the design phase but also should be considered in the concept phase. Designers and decision makers need to determine when and where these points come together. Designers must also consider ADA (Americans with Disabilities Act) requirements at these locations. With contractor involvement, designers can make design decisions that effectively integrate the contractor’s probable work plan. According to an industry expert “sometimes you restrict construction work to a specific area to limit contractor exposure; and use flaggers to keep pedestrians in line.” Although the actual mitigation of the interaction points hazard may occur at the construction phase it needs to be addressed in the design phase.

Several mitigation strategies where identified as associated with the design phase:

Contractor Involvement & Constructability:

During the focus group discussion, contractor involvement and constructability reviews were identified as mitigation strategies for work zone hazards. During this process the contractor responsibilities were also discussed. Contractors need to be involved when considering the constructability of the sequence of work; they need to be involved in an overall project safety responsibility program; and they need a voice in determining what construction allowances are available to ensure that the contractor is given enough time to complete the project. Also understanding and developing the communication needs within the construction team is something the contractor needs to be involved in. Some special considerations which the contractor needs to be involved in during the design process include: location of construction traffic staging areas; locations of borrow pits; and contractor access points. Often these issues are under the contractor's influence and need to be considered in the overall project process. As part of the bidding process, it may be desirable to specify that the contractor have a safety person on staff for the project, that there is an early and continuous communication plan in place, as well as a framework for reporting unsafe actions or near-misses. In general, the contractor selected for a project should be aware that safety is everyone's job and everyone's general responsibility.

Design Details/ Size & Complexity of Project:

One issue which expert panelists discussed was the practice of using generalized standard details on projects without consideration for project specifics such as size and complexity. In fact the question was raised, "Do smaller projects have a higher percentage of work zone crashes?" It is understood by the expert panel that in terms of roadway design, the general policy is to use standards even though it may not make sense for a given project geometry and topography. This could lead to unnecessary hazards in the construction of the project. Therefore a mitigating strategy is to start looking at design projects differently, on an individual basis, with less emphasis on standardized details.

An area that the focus group participants felt needed more specifications in order to mitigate work zone hazards was in specifying a "safe" height for drop offs in pavement milling jobs when building under traffic conditions.

Falling Debris:

For more complex projects, the sequencing and phasing of traffic required to mitigate against falling debris in projects involving overhead structures can be noted in the concept phase but also re-assessed in each of the following stages, particularly the design phase.

Driver Confusion / Unfamiliarity /Skills:

During the focus group, a detailed discussion was made about mitigating strategies which could be used to limit driver confusion. In general, an accepted mitigating strategy involves channelizing the motorists in such a way that there is no choice or thought required by the motorist into which route to take. The belief among the focus group participants was that the less reading for the driver, the better. Making the traffic barriers and markings move the traffic without effort from the driver is considered a good practice. Driver/operator unfamiliarity with the work zone needs to be considered a hazard that can cause motorists to become confused, leading to potential crashes. The focus group participants felt that project specific awareness initiatives could mitigate against driver unfamiliarity. A current mitigating strategy to bring about project awareness involves work zone initiatives programmed a year or so out to begin educating the public and press releases which are provided to local press venues following the letting process.

During the discussion, “driver skills” was identified as a work zone hazard that could be identified during all phases of the project. The exert panelists felt that as a whole driver training processes have been losing ground and programs focused on such efforts have failed.

More innovation in driver training, especially concerning the work zone environment is needed.

Traffic Control:

The panel participants also discussed the need for continuity of traffic control when there is a multiple prime in general proximity. Many times traffic control is applicable to the needs of the contractor who has originally designed and placed the traffic control; however this traffic control may or may not be in concert with the needs and objective of the other contractors. Therefore, more general oversight is needed in order to ensure continuity of the traffic control. One way to mitigate against this hazard is to work out solutions in contract language or by bid items for changes to traffic control.

A consensus of the focus group participants revealed that during the design phase, risks arising from inadequate traffic control can be best mitigated by the following: pavement marking design; construction traffic considerations (involving early contractor involvement); consideration of an out of distance program— targeting of a specific hauler or trucking company with information or incentives concerning avoiding or restricting their use of the area under construction—to reduce traffic from carriers; specifications for signage: traffic control; enforcement; specifications for flagger training; and adjustable speed limit specifications. In addition to specifications and designs, the focus group discussed the need to identify potential hazards/problems associated with alternate routes and detours from the perspective of as many qualified individuals as possible by actually driving the routes.

The focus group also identified the type of contract as a possible mitigation strategy. For instance, an itemized bid versus a lump sum contract may be utilized in order to administer adequate and relevant work zone traffic control. Since it is difficult to incentivize and penalize for work zone safety, a possible mitigating strategy against inadequate traffic control is for the DOT's to make the process easier for contractors to make changes to the standard design once the contract has been awarded. Flexibility provided in the contract will allow innovation to be applied rapidly.

The panel identified the lack of positive protection for workers within the work zone as a potential hazard. Therefore the industry professionals from the focus group identified the following as possible mitigation strategies: specify the ingress and egress of work area; specify law enforcement; specify separate pay items for traffic safety; specify high visibility apparel for all stakeholders. Many of these strategies are required on federally funded projects but the mitigation strategies should be required for all projects based on the risk assessment.

Letting & Award Phase

Outside of incomplete plans and general lack of contractor safety training, the focus group expressed particular concern over the contract period to ensure that the construction start date and the contract start date coincide to ensure that the work zone is not set up a long time before construction actually begins, as this could result in hazards from confused or inattentive drivers. In addition, from the perspective of the focus group, roadway projects typically lack adequate overall project management. Currently, in situations where there is more than one concurrent project in the same general proximity, the resident engineer typically retains project responsibility. It was the view of the focus group participants that contractor fines and sanctions for non-compliance to safety requirements and infractions would serve as mitigating strategies for contractor safety violations. In was the belief of focus group participants that in most cases, the low bid contracting method does not incentivize contractors for safety.

Other concerns come in the form of contractor selection. The focus group felt that contractors should be prequalified based on safety records and that they should be evaluated based on their safety performance on past projects. Since traffic control is essentially the contractor's responsibility, the expert panel felt that in order to ensure that the contractor is proactive; a mitigating strategy would involve fines issued for traffic control that is inadequate. The focus group also felt that there should also be increased levels of sanctions for safety infringements. Also, they felt that the contractor needs to have more ownership for on-site safety and surveillance. In the case where construction is spread over more than one construction season, the focus group participants felt that there must be provisions for interim phase coordination for signage during project transitions.

Construction Phase

Ultimately everything identified as a potential hazard in the earlier project phases will be realized during the construction phase. This is especially true if the hazard was identified, but not explicitly mitigated at an earlier phase.

Some specific issues and mitigating strategies encountered in the construction phase include:

Driver Skills:

During the discussion, the topic of driver characteristics came into play. It was noted that although driver characteristics are an important aspect of risk management hazard identification, there is very little that can be done to mitigate the problem. According to the focus group, many initiatives have been employed to shape driver characteristics, but in general driver skills and knowledge have worsened over the years due to a decreased ability to understand English, increased cell phone usage, and increases in poor attitude. Driver education programs have been removed from the public school systems, thereby allowing less opportunity to educate younger drivers. The current situation for license renewal requires a fee and a vision check – little is done to create a positive method to educate existing drivers. This is one area where innovative strategies could be designed and implemented to mitigate this particular hazard.

Signage:

Several mitigating strategies where suggested by the focus group participants to deal with hazards involving inadequate signage. One strategy involves the removal of signs that are not credible or simply do not apply to the situation. If work zone signs are posted and there is no activity, to the motorist, the sign is not credible and ultimately becomes a hazard. The focus group emphasized the use of multiple devices to get the attention of motorist. It was felt that limiting the number of signs which must be read by a motorist by employing a simple changeable message targeted directly at the motorist may be most effective. This simple message could be most effectively followed up with channelizing devices (jersey barriers, flashing arrows, etc.). Other important hazard mitigating strategies involve ensuring that signs are clean and serviceable and ensuring that tapers follow the updated MUTCD. Another suggested mitigating strategy includes alerting the motorist early, prior to the point in which a decision must be made. It was suggested that this is best accomplished with a changeable message sign (CMS) that is effective in providing the most up-to-date pertinent information. The CMS should be followed with flashing arrows. Simplicity was stressed by the participants, as too many traffic devices could serve as an additional hazard by confusing motorists.

Visibility:

To ensure that visibility is not an issue in the construction phase, focus group participants suggested that portable light sets be positioned in such a way to minimize glare and blinding of motorists and that visibility of workers is ensured by enforcing the wearing of high visibility apparel as specified in contracts.

Work Zone Length:

A mitigating strategy which was suggested for reducing hazards associated with congestion in the work zone is the concept of lane rentals by the contractor. In order to prevent contractors from utilizing more roadway than is absolutely necessary, it was recommended that contractors pay for lane rentals per unit of road taken from the travel lanes. This will reduce congestion in the travel lane thereby reducing the hazard associated with traffic congestion.

5.2.6 Survey Results

An online survey was created using the results of the focus group discussion. The hazards identified during the focus group were tabulated as shown in Appendix C. The hazards identified during the content analysis and by the focus group participants were placed according to the project phases in which they were likely to be relevant and addressable according to the interpretations of the individuals involved in the process. The purpose of the survey was to validate the findings of the expert panel and to ensure that the interpretations of the researcher were in general agreement with the views of industry professionals.

In general, the survey response was lower than desired; however, the information obtained from the surveys proved valuable in the validation process. In addition to responding to the survey questions, many survey respondents chose to fill in the supplied text boxes with comments and concerns pertaining to work zone hazards and the state of the practice in general. Surveys were sent to electronic mail lists from government (DOT's), consultants, and contractors. Of these groups nearly 50 responded to the survey, however, of these only 18 complete and useable responses were "submitted" to the web survey provider. It was surmised that the surveys were in-fact completed but were not submitted properly. Industry professionals were asked to complete only the portion of the survey which reflected their area of expertise (planning and programming, design, letting and award, or construction). Five industry professionals responded to the planning and programming phase section, three industry professionals responded to the design phase set of questions, none responded to the letting and award phase and ten responded to the construction phase.

The survey response rate adequately allowed for industry professionals to aid in the collection and validation of probable hazards associated with each phase of a typical highway project development process. Table 5.6.1 shows the responses to the survey, by developing a matrix of hazards and respective project phases. The limitation of this research is that survey respondents were not afforded the opportunity to place an identified hazard into a project phase. They were only allowed to agree or disagree with the placement that was made by the focus group and the researcher.

Essentially, thirty nine hazards were identified throughout the process. Ten hazards were identified during the planning and programming phase; twenty six hazards were identified during the design phase; fifteen hazards were identified during the letting and award phase; and thirty hazards were identified during the construction phase. The compilation of the results from the survey validation process is presented in table format. Table 5.6.1 displays the 39 hazards, the respective assessment number, and the project phase with which the hazard should be identified. A marker was chosen to signify the project phase in which the identified hazard would originate. The results of the survey are reported in such a way as to show the level of agreement from the survey respondents. For instance, if all respondents agreed with the placing of an identified hazard in a particular project phase, that hazard would be represented by a large filled circle. If more than 50% agreed, the hazard would be represented by a circular marker with a small dot in the center. And if less than

50% agreed, the hazard would be represented by an empty circle. Write-in responses are represented by an empty circle with a dashed outline. If none of the respondents agreed, no mark would have been utilized; however, there were no hazards that had 100% disagreement. It is however, noteworthy that sixteen of the hazards had 100% agreement in at least one project phase. Also, respondents for six of the hazards had 50% or more disagreement in at least one project phase. And one hazard (#28 Poor driver skills) had 80% disagreement (20% agreement) in one project phase. This is likely because practitioners feel that "poor driver skills" should be identified somewhere outside of the project development process.

Table 5.6.1a: Consolidated Work Zone Hazards by Project Phase – (hazard # 1 through #12 listed alphabetically)

	IDENTIFIED HAZARD	Assess #'s	PROJECT PHASE PLANNING & PROGRAMMING	DESIGN	LETTING & AWARD	CONSTRUCTION
1	a contract that does not include a final schedule showing project duration and event planning				○	
2	accelerated project completion requirements (i.e., overexposure of workers; inclement weather construction; external construction completion date requirement –harvest, overlay cure time, etc.)		• 50	• 60		• 56
3	build/rebuild under traffic (work on shoulder; intermittent or moving work)	1,2	● 100	● 100		• 56
4	construction vehicle traffic (dump trucks, flatbed, concrete mixer)	3,4,5	◌	• 75		• 90
5	contractor complacency				○	
6	contractor selection process				○	
7	dirty/non-serviceable signs/reflectors, etc.	6				● 100
8	driver / operator inattention	7		• 80		• 90
9	driver confusion from: too many decisions (especially at higher speeds); driver/operator unfamiliarity; inadequate/confusing traffic control	9,10		● 100		• 90
10	extra traffic volume through the work zone from: construction traffic; civic events; holidays; seasonal traffic/road use	45-56	● 100	• 80	○	• 90
11	falling debris/material from: overhead structures & blasting	11	● 100	• 80		• 80
12	high risk traffic: Fridays, evenings – (bar time), rush hour traffic	38-44		• 60	○	● 100

Table 5.6.1b: Consolidated Work Zone Hazards by Project Phase – (hazard # 13 through #24 listed alphabetically)

	IDENTIFIED HAZARD	Assess #'s	PROJECT PHASE: PLANNING & PROGRAMMING	DESIGN	LETTING & AWARD	CONSTRUCTION
13	inadequate buffer distance from travel lane to work area	12		● 100		● 100
14	inadequate contractor accountability for safety				○	
15	inadequate internal traffic control plans (ITCPs)					● 90
16	inclement weather			● 75		● 60
17	increased demand of, inadequate capacity/geometry & confusing layout of: detours; road closures; lane closures (moving & stationary)			● 80		● 90
18	increased number of commercial trucks on existing routes or alternate routes	16	● 50	● 80		● 50
19	jobsite congestion & traffic resulting in local traffic congestion and delays			● 80		● 100
20	lack of accident/near-miss reporting structure				○	◌
21	lack of contractor innovation in traffic control methods			○ 40	○	● 60
22	lack of contractor project management (directed toward safety)				○	
23	lack of positive control of traffic			● 100		● 100
24	lack of visibility: glare (from headlights or sun); lighting conditions	17,18, & 19		● 80		● 80

Table 5.6.1c: Consolidated Work Zone Hazards by Project Phase – (hazard # 25 through #35 listed alphabetically)

	IDENTIFIED HAZARD	Assess #'s	PROJECT PHASE: PLANNING & PROGRAMMING	DESIGN	LETTING & AWARD	CONSTRUCTION
25	missing information (documentation of risk assessment); incomplete plans (TCP's); and incomplete bid requirements				○	
26	multiple prime in general proximity (resulting in discontinuous work zone signage & discontinuous traffic control)			● 80	○	● 56
27	non-credible/non-current signs during interim season				○	● 89
28	poor driver skills: operator error; aggressive driving	20, 21		○ 20	○	○ 30
29	poor visibility of workers	22		● 80		◉ 100
30	previous paint lines (confusion)			◉ 100		● 90
31	railroads, pedestrian paths/travel routes & trail crossings	23, 23b	◉ 100	◉ 100		● 70
32	road characteristics through the work zone: roadway classifications; narrow bridges; narrower shoulders; intersections (intersections, ramps); fore slopes: blind spots; line of sight obstructions; limited visibility due to topography	24-28		◉ 100		● 80
33	the condition of roadway & extra traffic volume of: detours; head-to-head traffic shifts; and shoulder shifts	29	● 50	● 80		● 70
34	the points of merge	30	● 50	● 80		● 67
35	the posted speed through the work zone	31-35	◉ 100	◉ 100		● 78

Table 5.6.1d: Consolidated Work Zone Hazards by Project Phase – (hazard # 36 through "survey write-ins")

	IDENTIFIED HAZARD	Assess #'s	PROJECT PHASE: PLANNING & PROGRAMMING	DESIGN	LETTING & AWARD	CONSTRUCTION
36	**the work zone area being laid out long before construction actually begins**				○	
37	**too long of work zone length**			◌		● 60
38	**traffic congestion & delay through the work zone**	36	⬤ 100			
39	**traffic speed & speeding (i.e., excess traffic speed, and limited stopping distance)**	37		⬤ 100	○	● 90
A	***Gawker slow downs (mitigation strategy: acknowledge the disruptive traffic pattern for the area – this could affect outside of project limits***		◌			
B	***Cell phone use by drivers (mitigation strategy: signage that prohibits use)***			◌		
C	***Oversized Vehicles (mitigation strategy: alternate routes for oversized vehicle traveling routes)***			◌		
D	***Unprotected pavement drop-offs***					◌
E	***Jobsite enter / egress points***					◌

⬤ 100% agreement ● 50-99% agreement ○ <50% agreement or no-response ◌ "write-in"

5.3 ASSESSMENT OF CRASH DATA

In the following sections, the thirty nine hazards are evaluated to determine the ability to assess the frequency and severity that a hazard may pose on the risk of work zone crashes and fatalities. Of the thirty-nine hazards, twenty two were deemed to be closely represented by fields within the statewide crash database that was created from a compilation of accident reports prepared by investigating officers. A following section of this chapter will go into detail as to the research approach and findings of the assessment of these hazards. Following a discussion of the assessment of these risks, attention will return to the mitigation of the risks associated with each hazard. The results of the expert panel as written in the previous section highlight the mitigation strategies that may be implemented in each project phase. The third section of this chapter formalizes the results from the content analysis and develops a method of identifying mitigation strategies based on the stakeholder's ability to manage the risk and the project phase which may provide the most effective method to implement the mitigation strategy.

In the following section, the identified hazards from the focus group study and the survey were integrated, assessed, and quantified using data from the Iowa statewide crash data base. The Iowa crash database was queried to list data pertaining to work zones crashes as documented on the investigating officer's report. The integration of this information provides a methodology that can be utilized to employ actual crash data in providing a quasi-quantitative assessment of each hazard as identified in the previous section of this research.

In order to obtain descriptive statistics to describe the overall occurrence and severity of Iowa work zone crashes, a query was created to gather data for all severity levels of crashes from the year 2001 to 2008 as provided in the Iowa Department of Transportation – Saver Crash Data from the Office of Traffic and Safety. The data from 2008 was preliminary and may not be fully inclusive of all crash data for that year, but was included in this research because partial data concerning crashes most likely still represents a level of randomness required for a representative data set.

As shown in Table 5.7.0a, 5405 crashes occurred in work zones from 2001 to October 2008 as provided from the data extracted from the statewide crash database. The severity of each crash is as reported on the Iowa Department of Transportation "Investigating Officer's Report of Motor Vehicle Accident" (see Appendix F). This table shows the total number of crashes for each severity level; Fatal, Major Injury, Minor Injury, Possible/unknown Injury, and Property Damage only. The data shows that 1% of all of the total crashes resulted in fatalities, approximately 4% of all crashes were serious injury crashes, 11% were minor injury crashes, 19% were possible or unknown injury crashes, and approximately 65% were property damage only crashes.

Table 5.7.0a: Iowa Statewide Work Zone Crash Statistics—
Total number of crashes (2001 -2008*)

Year	No. of Fatal Crashes	No. of Serious Injury Crashes	No. of Minor Injury Crashes	No. of Possible/ unknown Injury Crashes	No. of Property Damage Only Crashes	Total Crashes
2001	8	9	44	74	222	357
2002	6	21	77	110	331	545
2003	6	25	75	143	515	764
2004	7	34	72	151	588	852
2005	7	31	98	176	527	839
2006	1	26	88	161	464	740
2007	5	28	56	111	439	639
2008*	7	27	69	135	431	669
Total	47	201	579	1061	3517	5405

*data from 2008 is preliminary and may not be all inclusive

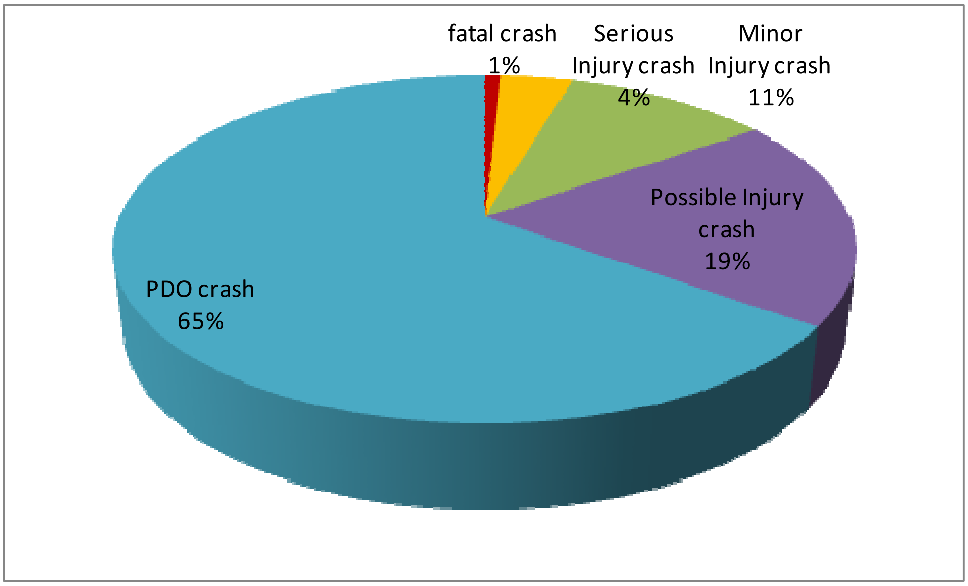


Figure 5.7.0a: Statewide Work Zone Crash Severity Distribution—Total crashes (2001 -2008)

This research analyzes data that includes the total number of vehicles involved in each of the crash severity levels. The purpose for including the total number of vehicles involved in a crash is to capture the characteristics of all participants in the crash event and to fully capture the characteristics and trends relating to crashes. When multiple vehicles are involved in a crash, the aggregate of the characteristics of each vehicle/driver may determine the severity of the crash. Crash severity level is determined by the most severe outcome for the crash-wide event as indicated by the severity field (denoted by "CSEVERITY" in the database).

Table 5.7.0b: Iowa Statewide Work Zone Crash Statistics—
Total vehicles involved in crashes (2001 -2008*)

Year	No. Vehicles involved in Fatal Crashes	No. Vehicles involved in Serious Injury Crashes	No. Vehicles involved in Minor Injury Crashes	No. Vehicles involved in Possible/ Unknown Injury Crashes	No. Vehicles involved in Property Damage Only Crashes	Total No. of vehicles involved in Crashes
2001	23	18	96	157	416	710
2002	17	52	174	250	663	1156
2003	9	39	130	294	988	1460
2004	11	68	150	306	1141	1676
2005	11	52	178	347	988	1586
2006	2	46	166	308	908	1430
2007	7	46	88	210	795	1146
2008	13	47	119	263	763	1205
Total	93	368	1101	2135	6672	10369
%	0.90	3.55	10.62	20.59	64.35	

*data from 2008 is preliminary and may not be all inclusive

Table 5.7.0b shows that a total of 10369 vehicles were involved in work zone crashes from 2001 to October 2008. A comparison of Table 5.7.0a and Table 5.7.0b reveals that on average approximately two vehicles (10369 vehicles / 5405 crashes = 1.9 veh./crash) were involved in each crash. This shows that each vehicle provides at least some contribution to the frequency and/or severity of every crash. The remainder of this chapter will focus only on the total number of vehicles involved in every type of crash. This will provide a larger data set to analyze and will provide more value in ascertaining the extent to which each identified hazard contributes to the frequency or severity of vehicle crashes in work zones.

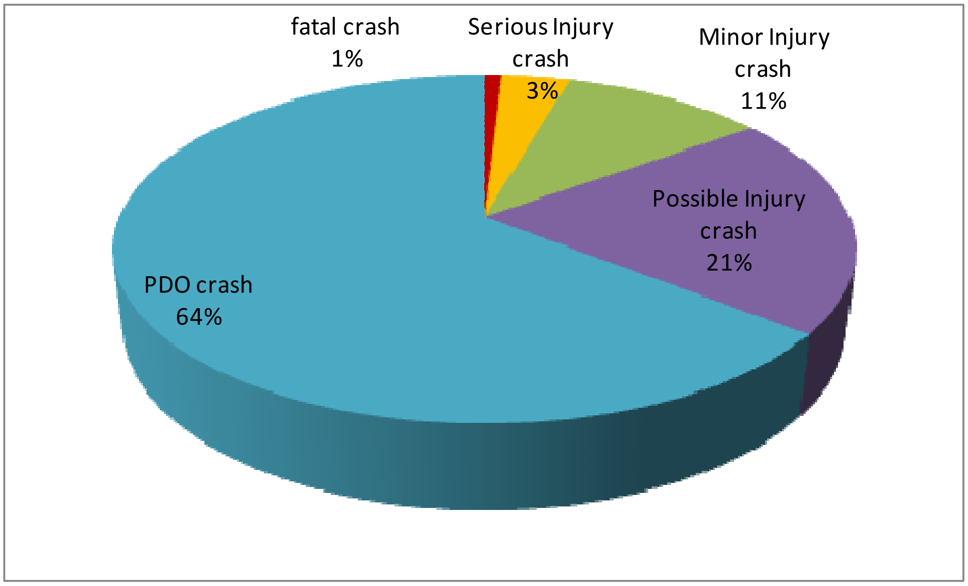


Figure 5.7.0b: Statewide Work Zone Crash Severity Distribution—

Total vehicles involved in crashes (2001 -2008)

Figure 5.7.0b. reveals that the work zone crash severity distribution of the total vehicles involved in crashes is very similar to the severity distribution of the total crashes. Of the total vehicles involved in work zone crashes, 1% were fatal crashes, 3% were major injury crashes, 11% were minor injury crashes, 21% were possible/unknown injury crashes, and 64% were property damage only crashes. Notably, a combination of fatal and serious injury crashes make up nearly 4% of all vehicles involved in crashes.

Ultimately, it is the severity distribution of all vehicle crashes that will be utilized to determine the relative severity of each of the identified work zone hazards, therefore, since the severity distribution of the total number of crashes was nearly the same as the severity distribution of the total number of vehicles involved in crashes, assessing the hazards using the data for all vehicles involved in each crash provided the greatest amount of sensitivity to the characteristics of the factors that impact the frequency or severity of work zone crashes.

5.3.1 Selection of Hazard Assessment Metrics

Considerable effort was undertaken in correlating the risk assessment of the identified work zone hazards to the collection of relevant crash data in order to provide the most applicable representation of the hazard as it pertains to the many coded entries on the investigating officer's report. Appendix F provides a copy of Form 433033 from the Iowa Department of Transportation "Investigating Officer's Report of Motor Vehicle Accident" utilized by the responding officer. It is this report and the accompanying codes and description of driver characteristics, vehicle characteristics, road characteristics, operating environment, and work zone condition as described in the previous chapter which provided the basis for assimilating the data. Unfortunately, the report is formatted to accommodate the investigating officer and not necessarily the transportation researcher; therefore, the factors that influence the crash are not explicitly listed on the report form. Therefore, great care was expended in order to extract the most applicable data field variables that can most closely represent the underlying concern of the identified hazard. This process was shown to be the most exhaustive component of the risk analysis process. Some researcher judgment was required to align an identified hazard to the available data variables of the crash report. However, the intent of this research is to develop a methodology that can be utilized to formalize the risk management of work zone crashes and fatalities with the understanding that the nature of risk management depends on the ability to standardize the approach to managing risk. Therefore, the decision-making process must take into account the limitations of the data, while at the same time, providing a reasonable correlation between the identified hazard and the data variable(s).

Table 5.7.0c: Grouping of Data Fields from Accident Report Data for Work Zone Crashes

Grouping /Factor	Data Field – (crash data)	Field Description
Driver characteristic	DCONTCIRC1 & DCONTCIRC2	Contributing Circumstance - Driver
	DL_STATE	Driver's License State
	SEQEVENTS1	Sequence of Event 1st Event
Road characteristic	RCONTCIRC	Contributing Circumstance - Roadway
	ROADTYPE	Type of Roadway Junction/Feature
Vehicle characteristic	CARGOBODY	Cargo Body Type
	VCONFIG	Vehicle Configuration
Operating environment	WEATHER1 & WEATHER2	Weather Conditions
	LIGHT	Light Conditions
	VISIONOBS	Vision Obscurement
	NM_ACTION	Non-Motorist Action
	TIME	Time of Crash
	DAY	Day of week
	MONTH	Month
Work zone condition	WZ_TYPE	Work Zone Type
	WZ_LOC	Location
	TRAFCONT	Traffic Controls
	SPEEDLIMIT	Posted Speed Limit

As discussed in the previous section, during the risk identification process, upon listing potential risks or hazards, the risk should be classified or grouped in order to aid the analysis and risk response functions. During the analysis of work zone hazards it was determined that there are essentially five groups or factors that influence the rate and severity of work zone crashes; driver characteristics, vehicle characteristics, road characteristics, operating environment, and work zone condition. Through the use of these factors or group classifications, several of the fields on the investigating officer's report were grouped for the purpose of correlating the correct factor grouping of identified hazards with the appropriate field in the accident report. The field names and values for the database are provided in Appendix G. Table 5.7.0c displays the grouping of these data fields.

For some of the identified hazards, the data fields were combined in order to properly categorize the risk. For instance, “construction vehicle traffic” was identified as a work zone hazard by the focus group/survey instruments. However, in the crash reports, data was grouped by both roadway condition and by vehicle type. Therefore, in the query only when the conditions “construction work zone” and “cargo body vehicle” (since construction vehicles are identified by the cargo body) were both met was the assumption made that the hazard of “construction vehicle traffic” was present. The data field for the cargo body was combined with the data field for the roadway contributing circumstance with the value corresponding to work zones. This assumes that vehicles with construction type cargo bodies involved in crashes that have been reported as work zone related roadway contributing circumstances infers that the combination of these two fields will yield a condition for assessing construction vehicle traffic. For this research, only the data fields for construction vehicle traffic were combined to represent a specific condition; all other hazards were represented by only one data field.

In some cases it was necessary to represent a hazard that has been grouped in one classification by a data field that has been grouped in different classification. For instance, “traffic congestion & delay” was identified as a work zone hazard according to the focus group/survey instruments, however under the classification “operating environment” on the crash report there is no entry for traffic congestion, therefore, it is assumed that evasive action (presumably from stop-and-go traffic) best represented the conditions of the hazard. However, evasive action is classified as a "driver characteristic" on the crash report and not "operating environment". This research qualifies that engineering judgment must be implemented in cases were the crash report may not explicitly represent identified hazards. The concept of the research is to develop the best approach to assessing hazards. Hazards assessed within the confines of objectivity based on basic assumptions are preferred to qualitative assessment based on "best guess".

5.3.2 Data Base Queries & Data Analysis

The data for this research was provided by the Iowa Department of Transportation in the form of statewide crash data from the years 2001 through 2008. The data from 2008 was preliminary (compiled October 2008) and may not be all inclusive of all crashes during that timeframe. However, since the nature of accidents is random in nature, all of the data files from 2008 were included in the analysis in order to create a larger data base from which to assess the characteristics of specific work zone hazards. The work zone data was compiled by Dr. Michael Pawlovich of the Iowa Department of Transportation from a larger statewide data base. The data compiled by Dr. Pawlovich includes only crashes from work zones and was pulled from a data base of all types of crashes occurring statewide. This data was provided in the form of a database file or .dbf. Microsoft Access® was utilized to design queries that extracted data from the database from specific data fields as provided on the motor vehicle accident report. In all, over 2400 queries were designed to extract data from 2001 through 2008 data base files. For each query, specific fields were identified and parameters were specified based on the desired output. The general requirements for each query was crash severity, vehicle number (the number given to each vehicle crash wide), and the field(s) of interest that best represents the identified hazard. Queries were performed to count the number of crashes for each of the five crash severity levels (fatal, major injury, minor injury, possible/unknown injury, and property damage only(PDO)) for each of the eight year periods, that correspond to the data field that best represents the identified work zone hazard.

5.3.3 Query Results and Descriptive Statistics of Each Hazard

In this section, database fields were associated with each of the hazards that were identified and validated during the focus group discussion and survey results. This section will discuss the assumptions made while associating the work zone hazard with the database variable. Once the database variable and field value were determined, a query was designed using Microsoft Access®. The dependent variable for each query was the crash severity which had values that ranged from 1 to 5 with 1=fatal crash, 2=major injury, 3=minor injury, 4=possible/unknown injury and 5=property damage only (PDO) crashes.

Each subsection will describe the database query assumption and will provide the descriptive statistics of each hazard. The purpose of this section is to present the distribution of vehicles involved in crashes with varying degrees of severity. This will allow for the development of a procedure to access the likelihood that a hazard will increase either the frequency or severity of a work zone crash. The goal of this section is to show the relative severity of each hazard with respect to the distribution of severity for all work zone crashes that were included in the statewide database from 2001 to October 2008.

Of the thirty nine hazards identified in the previous chapter, twenty two were selected to be assessed during this research. The remainder of the thirty nine hazards could not be represented or quantified through crash reports as they include factors such as: inadequate design, contractor apathy, or construction contractual issues, which would not appear on a crash report. Of the twenty two selected hazards, over fifty-six variable/value combinations were ultimately assessed. These assessment numbers are presented in the left hand column of each of the query tables in order to maintain a level of adequate data control. Each assessment however, represents a more specific hazard that falls under the general terms of the work zone hazard. The individual assessments of each hazard serve to provide a more detailed assessment of the hazard. Appendix H contains the raw data for each of the hazards that were queried during the database analysis.

#3) Build/rebuild under traffic

The results of this research identified build/rebuild under traffic as a hazard that could influence the frequency of severity of a work zone crash. Two separate variables were selected to represent the hazard of building or rebuilding under traffic. Shoulder and median work, along with intermittent or moving work were selected as variables to best describe the activities that constitute a situation where a decision to build under traffic was made. Table

5.7.1a describes the variables that were used to design the queries that provided the vehicle count for each crash severity level.

Table 5.7.3a: Database variables used to query "build/rebuild under traffic"

Assess #	Values Description	Values	Field Name	Field Description
1	Work on shoulder or median	3	WZ_TYPE	Type
2	Intermittent or moving work	4	WZ_TYPE	Type

Table 5.7.3b and Figure 5.7.3a show that 1514 vehicles were involved in work zone crashes where shoulder or median work was performed, of these vehicle crashes; 1% were fatal, 2% were serious injury, 10% were minor injury, 23% were possible injury, and 64% were property damage only crashes. Table 5.7.1b and Figure 5.7.1a also show that 559 vehicles were involved in work zone crashes where intermittent or moving work was performed. Of these crashes; 1% were fatal, 4% were serious injury, 12% were minor injury, 16% were possible injury, and 67% were property damage only. The sum of fatal and serious injury crashes equate to approximately 3% of the total vehicles involved in crashes where work was performed on "shoulders or median" and 5% of the total vehicles involved in crashes where work was "intermittent or moving." These are relatively close to the 4% computed for fatal and serious injury crashes for all work zone crashes. In addition, the query results provided descriptions of the frequencies of work zone crashes under the build/rebuild condition: the frequency of vehicle crashes on shoulder or median work is roughly 15% of all work zone crashes, whereas, the frequency of vehicle crashes in work zones with intermittent or moving work is 5% of all statewide work zone crashes.

Table 5.7.3b: Vehicle Crash distribution for "build/rebuild under traffic"

	Assess # 1 **work on shoulder or median**		Assess # 2 **intermittent or moving work**	
Crash Severity	# Veh. involved	%	# Veh. involved	%
Fatal	12	0.79%	7	1.25%
Serious Injury	35	2.31%	22	3.94%
Minor Injury	145	9.58%	65	11.63%
Possible Injury	351	23.18%	92	16.46%
Property Damage Only	971	64.13%	373	66.73%
Total	1514	Total	559	

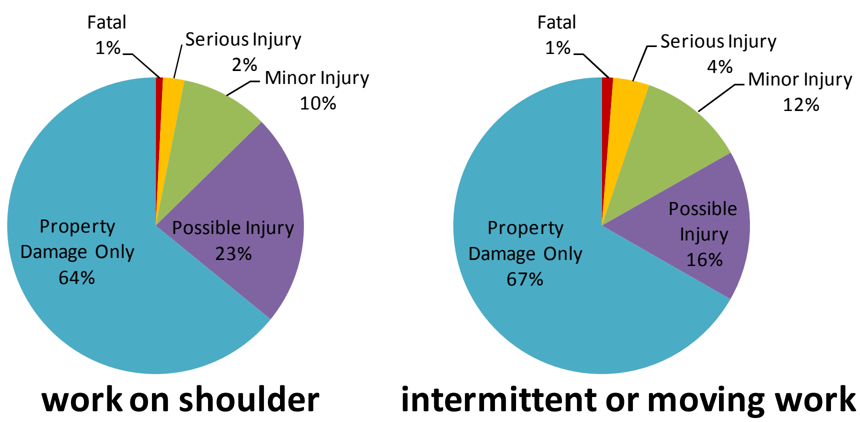


Figure 5.7.3a: Severity distribution(s) for "build/rebuild under traffic"

#4) Construction vehicle traffic

As described earlier, construction vehicle traffic was assessed using a combination of database fields. The roadway contributing circumstance of “work zone” was queried with cargo body type in order to best represent the identified hazard (Table 5.7.4a). This assumption, presumes that the investigating officer associated the type of vehicle with the work activities.

Table 5.7.4a: Database variables used to query “construction vehicle traffic”

Assess #	Values Description	Values	Field Name	Field Description
3	Truck Cargo Type: Dump truck (grain/gravel)	3	CARGOBODY	Cargo Body Type
	Work Zone (construction/maintenance/utility)	5	RCONTCIRC	Contributing Circumstance - Roadway
4	Truck Cargo Type: Flatbed	5	CARGOBODY	Cargo Body Type
	Work Zone (construction/maintenance/utility)	5	RCONTCIRC	Contributing Circumstance - Roadway
5	Truck Cargo Type: Concrete mixer	6	CARGOBODY	Cargo Body Type
	Work Zone (construction/maintenance/utility)	5	RCONTCIRC	Contributing Circumstance - Roadway

Table 5.7.4b and Figure 5.7.4a show that a total of 184 dump trucks were involved in work zone crashes from 2001 to 2008 with 2% involved in fatal crashes, 7% involved in serious injury crashes, 11% involved in possible injury crashes and 63% involved in PDO crashes. Ninety four flatbed cargo bodies were involved in crashes. Three percent of which were fatal crashes,7% were serious injury crashes, 10% were minor injury crashes, 14% were possible injury crashes and 66% were involved in PDO crashes. The concrete mixer cargo

body had only 22 crashes during the time frame between 2001 and 2008. There were no fatal or serious injury crashes involving concrete mixers. The sum of fatal and serious injury crashes equate to approximately 9% and 10% of the total number of dump truck and flat bed trucks involved in crashes respectively. These are over twice the 4% computed for fatal and serious injury crashes for all work zone crashes. The frequency of dump truck crashes in work zones is roughly 2% of all work zone crashes, the frequency of flat bed truck crashes in work zones is roughly 1% of all statewide work zone crashes, and concrete mixer crashes are less that 0.2% or all statewide work zone crashes.

Table 5.7.4b: Vehicle Crash distribution for "construction vehicle traffic"

	Assess # 3 Dump Truck		Assess # 4 Flat Bed		Assess # 5 Concrete Mixer	
Crash Severity	# Veh. involved	%	# Veh. Involved	%	# Veh. involved	%
Fatal	4	2.17%	3	3.19%	0	0.00%
Serious Injury	12	6.52%	7	7.45%	0	0.00%
Minor Injury	32	17.39%	9	9.57%	3	13.64%
Possible Injury	20	10.87%	13	13.83%	4	18.18%
Property Damage Only	116	63.04%	62	65.96%	15	68.18%
Total	184	Total	94	Total	22	

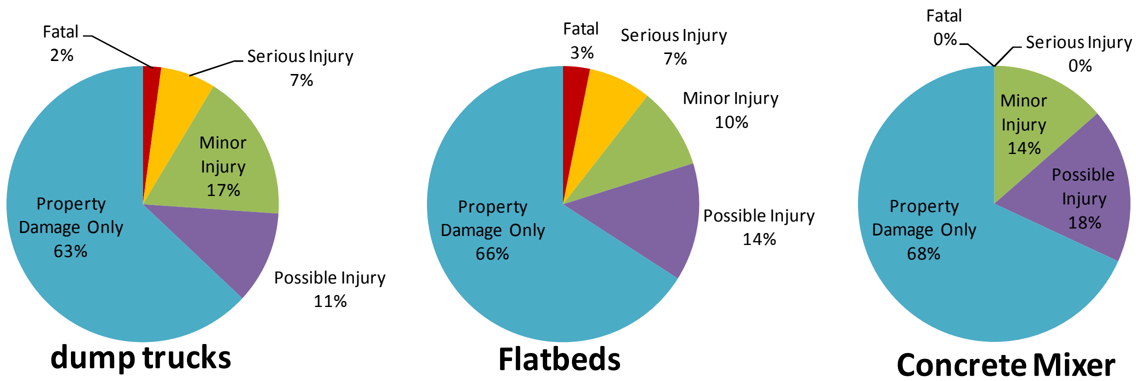


Figure 5.7.4a: Severity distribution(s) for "construction vehicle traffic"

#7) Dirty/non-serviceable signs/reflectors, etc.

Dirty and non-serviceable signs were directly represented by the entries on the accident reports. Table 5.7.7a shows that the traffic control device field contains a value for inoperative, missing and obscured traffic control devices. The query of crash data yielded a total of twenty one vehicles involved in crashes that were reported to have a roadway contributing circumstance where the traffic control device was an issue. Table 5.7.7b and Figure 5.7.7a show that for this identified hazard, there were no vehicles that were involved in fatal crashes, however, 5% were involved in serious injury crashes. Forty three percent were involved in possible injury crashes and 11% were involved in property only crashes. The sum of fatal and serious injury crashes equate to approximately 5% of the total number of vehicles involved in crashes. This is larger than the 4% computed for fatal and serious injury crashes for all work zone crashes. The frequency of crashes in work zones where the traffic control device is “dirty or non-serviceable” is roughly 0.2% of all statewide work zone crashes.

Table 5.7.7a: Database variables used to query “dirty/non-serviceable signs/reflectors, etc.”

Assess #	Values Description	Values	Field Name	Field Description
6	Traffic control device inoperative/missing/obscured	8	RCONTCIRC	Contributing Circumstance - Roadway

Table 5.7.7b: Vehicle Crash distribution for “dirty/non-serviceable signs/reflectors, etc.”

Assess #	Crash Severity	# Veh. involved	%
6	Fatal	0	0.00%
	Serious Injury	1	4.76%
	Minor Injury	0	0.00%
	Possible Injury	9	42.86%
	Property Damage Only	11	52.38%
	Total	21	

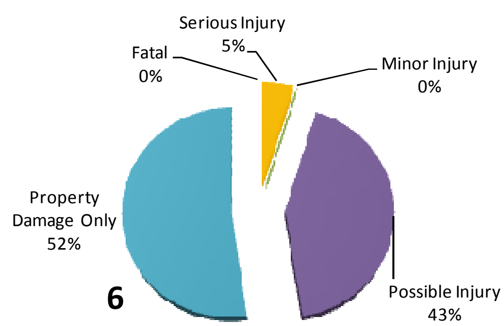


Figure 5.7.7a: Severity distribution for “dirty/non-serviceable signs/reflectors, etc.”

#8) Driver/operator inattention

Driver and operator inattention was acquired directly from the crash data fields. There were no assumptions made during the database query process. However, this analysis combined all of the values from the driver contributing circumstance field. The data base included four separate conditions or values that further explain the reason a driver was inattentive or distracted (Table 5.7.8a). This research combined all of the circumstances that caused the driver to be distracted.

Table 5.7.8a: Database variables used to query "driver/operator inattention"

Assess #	Values Description	Values	Field Name	Field Description
7	Inattentive /distracted by: Passenger	22	DCONTCIRC1 & DCONTCIRC2	Contributing Circumstance - Driver
	Inattentive /distracted by: Use of phone or device	23		
	Inattentive /distracted by: Fallen object	24		
	Inattentive /distracted by: Fatigued/asleep	25		

Table 5.7.8b and Figure 5.7.8a show that 169 vehicles crashes reported "inattentive/distracted" as the driver contributing circumstance. Of the total number of crashes were the driver was inattentive, zero were fatal, 12% were serious injury crashes, 8% were minor injury crashes, 27% were possible injury crashes and 53% were property damage only crashes. The sum of fatal and serious injury crashes equate to approximately 12% of the total number of vehicles involved in crashes. This is approximately three times larger than the 4% computed for fatal and serious injury crashes for all work zone crashes. The frequency of crashes in work zones with "driver/operator inattention" is roughly 1.6% of all statewide work zone crashes.

Table 5.7.8b: Vehicle Crash distribution for "driver/operator inattention"

Assess #	Crash Severity	# Veh. involved	%
7	Fatal	0	0.00%
	Serious Injury	20	11.83%
	Minor Injury	14	8.28%
	Possible Injury	46	27.22%
	Property Damage Only	89	52.66%
	Total	169	

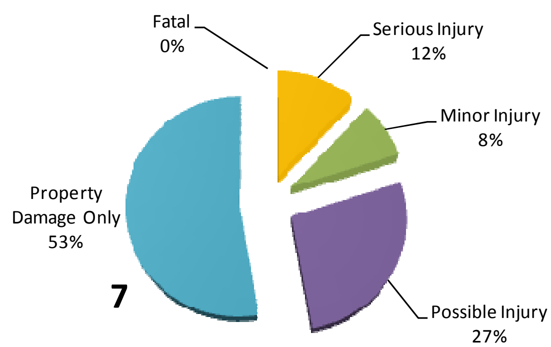


Figure 5.7.8a: Severity distribution for "driver/operator inattention"

#9) Driver confusion from: driver/operator unfamiliarity (out-of-state driver license)

Since the vehicle crash reports do not explicitly ascertain driver information pertaining to driver confusion, some inferences were made concerning this hazard. It can safely be assumed that out-of-state drivers would be unfamiliar with the highway work zone conditions; however this assumption does not capture the number of in-state drivers who may not be familiar with the construction project (Table 5.7.9a). This does, however, take into account that nearly all out-of-state drivers would be unfamiliar with the construction project and would provide beneficial information as to the impact that the work zone design and layout may impart on the traveling public.

Table 5.7.9a: Database variables used to query "driver/operator unfamiliarity"

Assess #	Values Description	Values	Field Name	Field Description
9	All out-of-state (Iowa) driver's license		DL_STATE	Driver's License State

Table 5.7.9b and Figure 5.7.9a show that one thousand nine hundred and sixty-nine out-of-state vehicles were involved in work zone crashes. Of those, 2% were fatal crashes, 4% were serious injury crashes, 11% were minor injury crashes, 19% were possible injury crashes and 65% were property damage only crashes. The sum of fatal and serious injury crashes equate to approximately 6% of the total number of vehicles involved in crashes. This is greater than the 4% computed for fatal and serious injury crashes for all work zone crashes. The frequency of crashes in work zones involving drivers/operators with out-of-state driver license is roughly 19% of all statewide work zone crashes.

Table 5.7.9b: Vehicle Crash distribution for "driver/operator unfamiliarity"

Assess #	Crash Severity	# Veh. involved	%
9	Fatal	33	1.68%
	Serious Injury	82	4.16%
	Minor Injury	211	10.72%
	Possible Injury	370	18.79%
	Property Damage Only	1273	64.65%
	Total	1969	

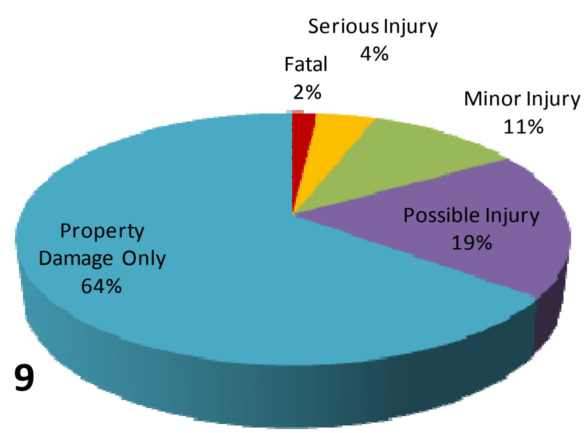


Figure 5.7.9a: Severity distribution for "driver/operator unfamiliarity"

#9) Driver confusion from: inadequate/confusing traffic control (no controls present)

As mentioned in the previous section, it is difficult to determine if the driver was confused prior to being involved in a work zone crash. However, there are fields within the crash data that infer confusion by documenting whether or not controls were present (Table 5.7.9c). The lack of traffic control is one component of the overall hazard on inadequate or confusing traffic control. Since this is an exercise in risk management, the intent is to raise awareness of specific hazards. This means that even though the assessment of this hazard may not adequately capture all evidence of inadequate or confusing traffic control it capture a portion of the hazard which still provides value to the risk management team. Essentially, if the risk is assessed to be relatively high based on limited data, it more than likely is more severe of a risk than the data suggests.

Table 5.7.9c: Database variables used to query "inadequate/confusing traffic control"

Assess #	Values Description	Values	Field Name	Field Description
10	No controls present	1	TRAFCONT	Traffic Controls
	Unknown	99		

Table 5.7.9d and Figure 5.7.9c show that four thousand eight hundred and fifty-six vehicles were involved in crashes that were reported to have no traffic controls present (or unknown controls). Of these crashes, 1% were fatal, 3% were serious injury, 10% were minor injury, 20% were possible injury, and 65% were property damage only. The sum of fatal and serious injury crashes equate to approximately 4% of the total number of vehicles involved in crashes. This is similar to the 4% computed for fatal and serious injury crashes for all work zone crashes. The frequency of crashes in work zones where no traffic controls were present is roughly 47% of all statewide work zone crashes.

Table 5.7.9d: Vehicle Crash distribution for "inadequate/confusing traffic control"

Assess #	Crash Severity	# Veh. involved	%
10	Fatal	39	0.80%
	Serious Injury	161	3.32%
	Minor Injury	492	10.13%
	Possible Injury	995	20.49%
	Property Damage Only	3169	65.26%
	Total	4856	

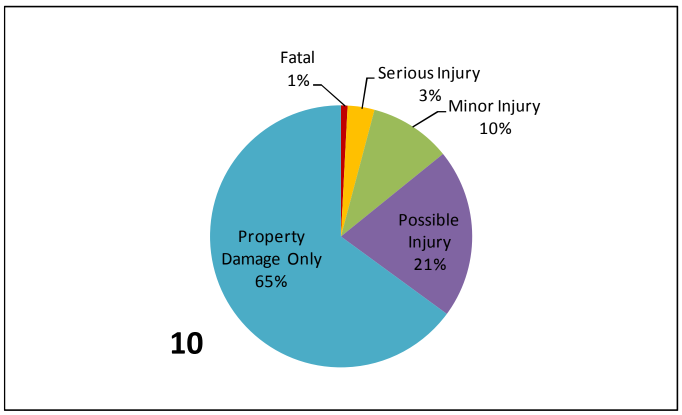


Figure 5.7.9c: Severity distribution for "inadequate/confusing traffic control"

#11) Falling debris/material (fallen object)

Fallen objects has been identified as a hazard that could increase the frequency or severity of a work zone crash. The crash report was limited in terms of specifically identifying a condition that addresses falling debris/materials. Therefore, the assumption was made to identify "distraction by fallen object" as a field to represent this hazard (Table

5.7.11a). The crash data does not specify if the fallen object was specifically related to the construction activity, however, the results show the necessity to develop mitigation strategies related to fallen objects in work zones.

Table 5.7.11a: Database variables used to query "falling debris/material"

Assess #	Values Description	Values	Field Name	Field Description
11	Fallen object	24	DCONTCIRC1 & DCONTCIRC2	Contributing Circumstance - Driver

Table 5.7.11b: Vehicle Crash distribution for "falling debris/material"

Assess #	Crash Severity	# Veh. involved	%
11	Fatal	0	0.00%
	Serious Injury	5	15.15%
	Minor Injury	2	6.06%
	Possible Injury	13	39.39%
	Property Damage Only	13	39.39%
	Total	33	

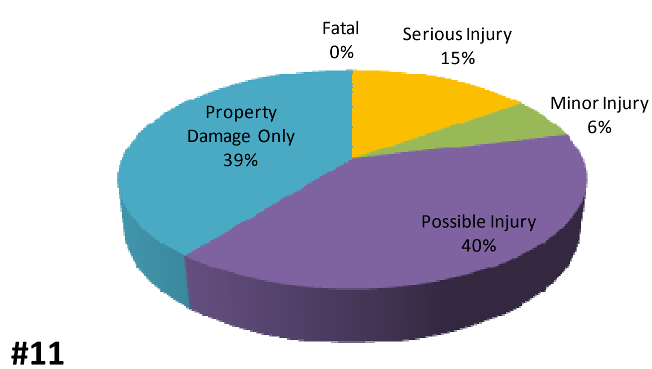


Figure 5.7.11a: Severity distribution for "falling debris/material"

Table 5.7.11b and Figure 5.7.11a shows that thirty-three vehicle crashes involved "fallen objects." The data shows that there were no fatal crashes, however, 15% of these crashes were in fact, serious injury crashes, 6% were minor injury crashes and possible injury and property damage only crashes were 39% of the total number of vehicles involved in crashes involving fallen objects. The combination of fatal and serious injury crashes constitute 15% of the total number of vehicles involved in crashes. This is over three times the 4% computed for fatal and serious injury crashes for all work zone crashes. The frequency of crashes in work zones involving "fallen objects or debris" is roughly 0.3% of all statewide work zone crashes.

#13) inadequate buffer distance from travel lane to work area

It is difficult to determine the adequacy of the buffer distance between the travel lane and the work area. In this case, it was determined that the identification of vehicle crashes "within or adjacent to the work activity" would provide relevant and significant information regarding the design and layout of the highway construction project (Table 5.7.13a). Therefore, although the data provided may not explicitly identify whether or not the buffer distance is adequate, it does however, allow researchers to identify the location within the work zone that may require a more innovative approach to design, layout or traffic control of the project area.

Table 5.7.13a: Database variables used to query "inadequate buffer distance"

Assess #	Values Description	Values	Field Name	Field Description
12	Within or adjacent to work activity	4	WZ_LOC	Location

Table 5.7.13b: Vehicle Crash distribution for "inadequate buffer distance"

Assess #	Crash Severity	# Veh. involved	%
12	Fatal	25	0.58%
	Serious Injury	156	3.59%
	Minor Injury	465	10.71%
	Possible Injury	907	20.89%
	Property Damage Only	2789	64.23%
	Total	4342	

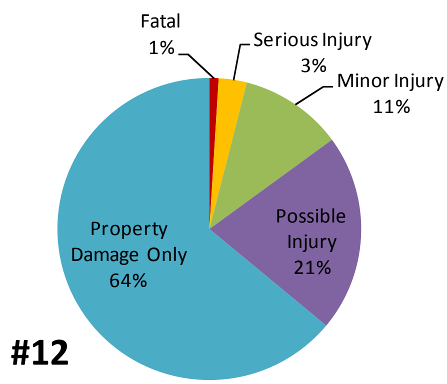


Figure 5.7.13a: Severity distribution for "inadequate buffer distance"

Table 5.7.13b and Figure 5.7.13a show that four thousand three hundred and forty-two vehicles were involved in crashes were within or adjacent to the work activity area. Of these vehicle crashes, 1% were fatal, 3% were serious injury, 11% were minor injury, 21%

were possible injury and 64% were property damage only crashes. The combination of fatal and serious injury crashes total approximately 4% of all crashes within or adjacent to the work activity area that were annotated on the accident report. This is the same as the 4% computed for fatal and serious injury crashes for all work zone crashes. The frequency of vehicle crashes in work zones that were "within or adjacent to the work area" is roughly 42% of all statewide work zone vehicle crashes.

#16) inclement weather

For the identified hazard of "inclement weather", the accident report contains several fields that document the weather conditions at the time of the crash. Table 5.7.16a shows the values of each of the inclement weather conditions that were included in the query design that was used to provide the data for the assessment of this hazard. For this hazard no additional assumptions were made to correlate the identified hazard with the variable fields of the statewide crash database.

Table 5.7.16a: Database variables used to query "inclement weather"

Assess #	Values Description	Values	Field Name	Field Description
13	Fog/smoke	4	WEATHER1 & WEATHER2	Weather Conditions
	Mist	5		
	Rain	6		
	Sleet/hail/freezing rain	7		
	Snow	8		

Table 5.7.16b and Figure 5.7.16a, show the distribution of the nine hundred and twenty vehicles that were involved in crashes that were reported to occur during times of inclement weather. Of those crashes, 1% were fatal, 4% were serious injury, 13% were minor injury, 20% were possible injury, and 62% were property damage only crashes. The total of fatal and serious injury crashes during times of inclement weather constitute approximately 5% of the total of all crashes that occur during those times. This is slightly larger than the 4% of combined fatal and serious injury crashes for all work zone crashes. The frequency of vehicle crashes in work zones involving inclement weather is roughly 9% of all statewide work zone vehicle crashes.

Table 5.7.16b: Vehicle Crash distribution for "inclement weather"

Assess #	Crash Severity	# Veh. involved	%
13	Fatal	9	0.97%
	Serious Injury	42	4.55%
	Minor Injury	119	12.88%
	Possible Injury	184	19.91%
	Property Damage Only	570	61.69%
	Total	924	

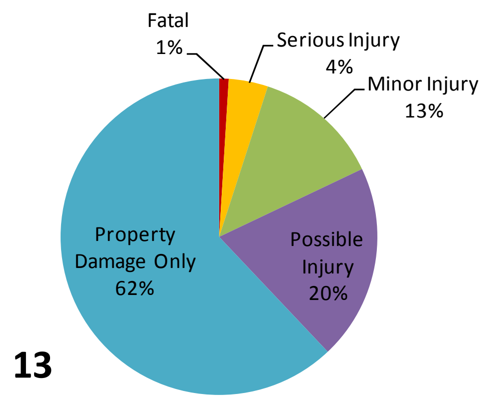


Figure 5.7.16a: Severity distribution for "inclement weather"

#17) Increased demand, inadequate capacity/geometry & confusing layout of: lane closures; road closures

The increased demand, inadequate capacity or geometry and the potential confusing layout of lane closures and road closures is difficult to directly quantify using the statewide crash data for roadway work zones. Even though concepts such as confusing geometry or inadequate capacity cannot be directly correlated with fields on the crash reports, certain types of work zones such as lane closures or head-to-head traffic situations will be likely indicators of such a hazard. Table 5.7.17a shows that database variables for work zone type were used with the value of either "lane closure" or "head-to-head traffic" as the two conditions that were queried to provide data that would best serve as a descriptive method to assess the likelihood or severity of crashes that occur. This means that risk managers will need to determine how the database query results may be utilized to best represent their unique work zone situation.

Table 5.7.17a: Database variables used to query "lane closures; road closures"

Assess #	Values Description	Values	Field Name	Field Description
14	Lane closure	1	WZ_TYPE	Type
15	Lane shift/crossover (head-to-head traffic)	2	WZ_TYPE	Type

Table 5.7.17b: Vehicle Crash distribution for "lane closures; road closures"

	Assess # 14 Lane Closure		Assess # 15 Lane Shift/crossover	
Crash Severity	# Veh. involved	%	# Veh. Involved	%
Fatal	31	0.65%	22	1.82%
Serious Injury	172	3.63%	53	4.38%
Minor Injury	503	10.61%	135	11.17%
Possible Injury	1010	21.31%	215	17.78%
Property Damage Only	3023	63.79%	784	64.85%
Total	4739	Total	1209	

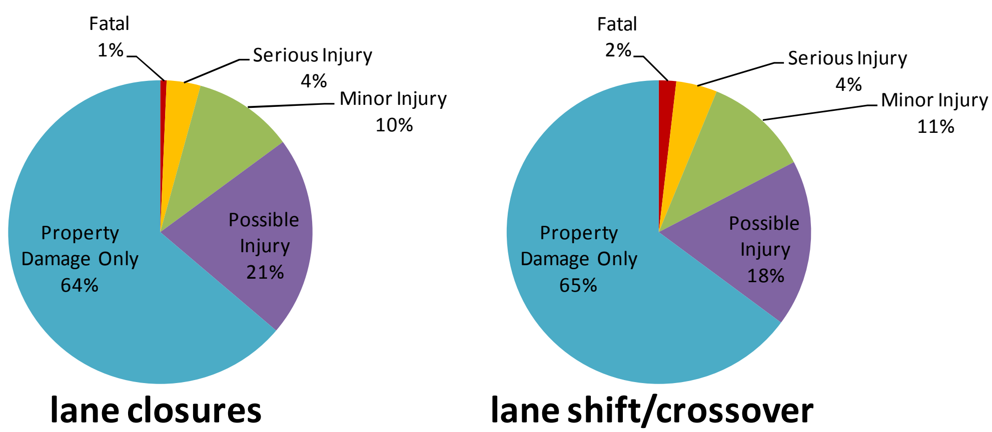


Figure 5.7.17a: Severity distribution for "lane closures; road closures"

Table 5.7.17b and Figure 5.7.17a show that a total of 4739 vehicles were involved in crashes with lane closure as the work zone type. Of these 1% were fatal crashes, 4% were serious injury crashes, 10%were minor injury crashes, 21% were possible injury crashes and 64% were PDO crashes. Table 5.7.17b and Figure 5.7.17a also show that 1209 vehicles were involved in crashes with lane shift/crossover as the work zone type; 2% of which were fatal crashes,4% were serious injury crashes, 11% were minor injury crashes, 18% were possible injury crashes and 65% were involved in PDO crashes. The sum of fatal and serious injury crashes equate to approximately 5% and 6% of the total number of vehicles involved in lane closure and lane shift/crossover crashes respectively. These are almost one and a half times the 4% computed for fatal and serious injury crashes for all work zone crashes. The frequency of vehicle crashes in work zones with “lane closures” is roughly 46% of all statewide work zone crashes; whereas, the frequency of vehicle crashes in work zones with “lane shift/crossover (head-to-head)” is roughly 12% of all statewide work zone vehicle crashes.

#18) Increased number of commercial trucks on existing routes or alternate routes

In order to assess an increase in the number of commercial trucks on existing or alternate routes, it was necessary to first assess the effects of commercial trucks on work zones. Therefore, the body configurations of the vehicles involved in work zone crashes were queried. For this hazard, vehicle configurations were queried that best resembled commercial trucks. Table 5.7.18a shows the database value and description of all configurations that were used in this section to be included in the query to extract data pertaining to the type of vehicles that are involved in work zone crashes. Ultimately, this assessment shows that commercial vehicle traffic contributes to the frequency and severity or work zone crashes.

Table 5.7.18a: Database variables used to query "increased number of commercial trucks"

Assess #	Values Description	Values	Field Name	Field Description
16	Single-unit truck (2-axle/6-tire)	5	VCONFIG	Vehicle Configuration
	Single-unit truck (>=3-axle)	6		
	Truck/trailer	7		
	Truck tractor (bobtail)	8		
	Tractor/semi-trailer	9		
	Tractor/doubles	10		
	Tractor/triples	11		
	Other heavy trucks (cannot classify)	12		

Table 5.7.18b: Vehicle Crash distribution for "increased number of commercial trucks"

Assess #	Crash Severity	# Veh. involved	%
16	Fatal	23	2.26%
	Serious Injury	60	5.91%
	Minor Injury	114	11.22%
	Possible Injury	141	13.88%
	Property Damage Only	678	66.73%
	Total	1016	

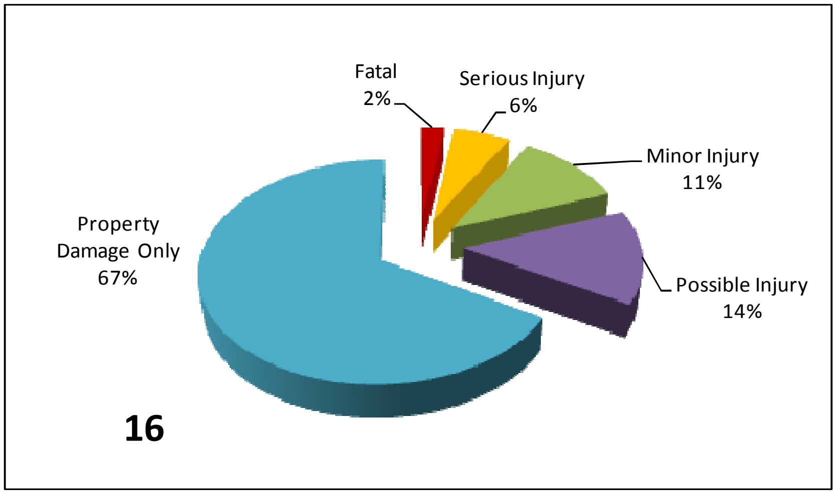


Figure 5.7.18a: Severity distribution for "increased number of commercial trucks"

Table 5.7.18b and Figure 5.7.18a show that a total of 1016 vehicles with "commercial" configurations were involved in work zone crashes from 2001 through October 2008. Of these 2% were fatal crashes, 6% were serious injury crashes, 11%were minor injury crashes, 14% were possible injury crashes and 67% were PDO crashes. The combination of fatal and serious injury crashes equate to approximately 8% of the total number of commercial vehicles involved work zone crashes. This is twice the 4% of the combined fatal and serious injury crashes for all work zone crashes. The frequency of "commercial truck" crashes in work zones is roughly 10% of all statewide work zone vehicle crashes. The assumption can be made that the severity of crashes involving commercial trucks will be an important issue in risk assessment, whether or not these trucks are traveling on existing or on alternate routes as related to work zones.

#24) Lack of visibility/glare/lighting

For the hazard identified as “lack of visibility from glare or light conditions”, the statewide crash data has fields that directly apply. Table 5.7.24a, shows three query assessment numbers and field descriptions of the database variables. The descriptions include: blinded by sun or head lights; dark-road ways lighted; and dark roadway not lighted.

Table 5.7.24a: Database variables used to query “lack of visibility/glare/lighting”

Assess #	Values Description	Values	Field Name	Field Description
17	Blinded by sun or headlights	10	VISIONOBS	Vision Obscurement
18	Dark – roadway lighted	4	LIGHT	Light Conditions
19	Dark – roadway not lighted	5	LIGHT	Light Conditions

Table 5.7.24b: Vehicle Crash distribution for “lack of visibility/glare/lighting”

	Assess # 17 Blinded by sun or headlights		Assess # 18 Dark Roadway lighted		Assess # 19 Dark Roadway not lighted	
Crash Severity	# Veh. involved	%	# Veh. involved	%	# Veh. involved	%
Fatal	1	1.61%	12	1.33%	19	3.30%
Serious Injury	4	6.45%	25	2.77%	39	6.77%
Minor Injury	10	16.13%	92	10.21%	95	16.49%
Possible Injury	14	22.58%	180	19.98%	110	19.10%
Property Damage Only	33	53.23%	592	65.70%	313	54.34%
Total	62	Total	901	Total	576	

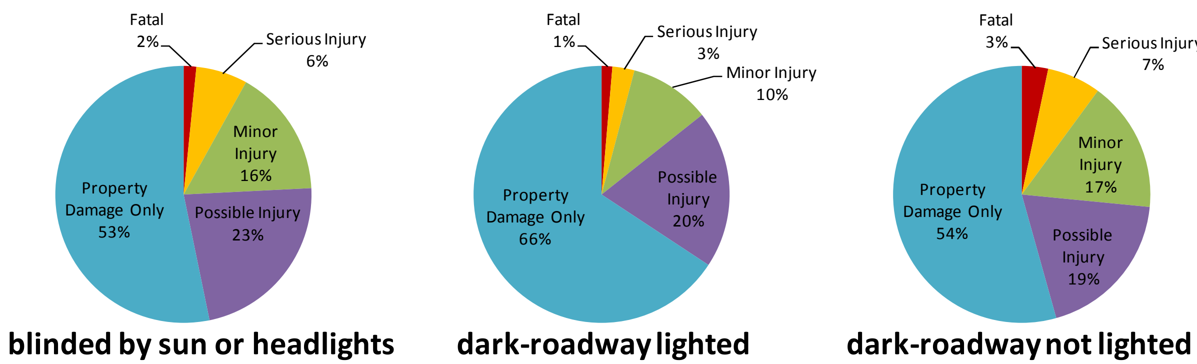


Figure 5.7.24a: Severity distribution for “lack of visibility/glare/lighting”

Table 5.7.24b and Figure 5.7.24a show that of the 62 vehicles were reported to be blinded by the sun or head lights, 2% were fatal, 6% were serious injury, 16 % were minor injury, 23% were possible injury and 53% were property damage only. Nine hundred and one vehicle crashes were reported on lighted roadways at dark; of these 1% were fatal, 3% were serious injury, 10% were minor injury, 20% were possible injury, and 66% were property damage only. Meanwhile on dark roadways where work zones that were not lighted, 576 vehicles were involved in crashes where 3% were fatal, 7% were serious injury, 17% were minor injury, 19% were possible injury, and 54% were property damage only. For these conditions of lack of visibility the combined fatal and serious injury distributions for being blinded by sun or headlights, lighted roadways, and unlighted roadways were 8%, 4%, and 10% respectively. This is compared to the 4% of the combined fatal and serious injury crashes for all work zone crashes. The frequency of vehicles involved in work zone crashes where the driver was “blinded by the sun or headlights” is roughly 0.6% of all statewide work zone crashes. The frequency of vehicle crashes during the hours of dark where the work zone was lighted is roughly 9% of all statewide work zone vehicle crashes. The frequency of vehicle crashes during the hours of dark where the work zone was not-lighted is roughly 6% of all statewide work zone vehicle crashes.

#28) Poor driver skills (operator error & aggressive driving)

The identified hazard of poor driver skills was generically grouped with those of general operator error; however, aggressive and erratic behavior was extracted from this group in order to highlight the two as separate conditions. Table 5.7.28a shows the field names and variables used to describe the conditions of driver contributing circumstances from the database that best represent the identified hazard of "poor driver skills" represented by operator error and aggressive driving.

Table 5.7.28a: Database variables used to query "poor driver skills"

Assess #	Values Description	Values	Field Name	Field Description
20	Ran traffic signal	1	DCONTCIRC1	Contributing Circumstance - Driver
	Ran stop sign	2		
	Driving too fast for conditions	4		
	Made improper turn	5		
	Traveling wrong way or on wrong side of road	6		
	Crossed centerline	7		
	Lost control	8		
	Followed too close	9		
	Over correcting/over steering	11		
21	Operating vehicle in an erratic/reckless/ careless/negligent/aggressive manner	12	DCONTCIRC1	Contributing Circumstance - Driver

Table 5.7.28b: Vehicle Crash distribution for "poor driver skills"

	Assess # 20 Operator Error		Assess # 21 Aggressive Driving	
Crash Severity	# Veh. Involved	%	# Veh. involved	%
Fatal	20	0.78%	6	2.78%
Serious Injury	105	4.09%	13	6.02%
Minor Injury	296	11.53%	37	17.13%
Possible Injury	545	21.22%	36	16.67%
Property Damage Only	1602	62.38%	124	57.41%
Total	2568	Total	216	

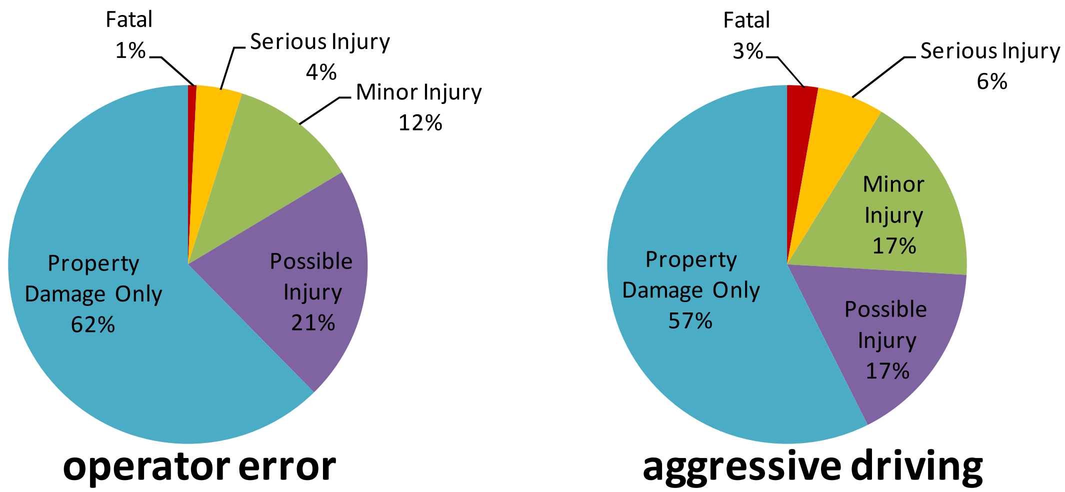


Figure 5.7.28a: Severity distribution for "poor driver skills"

Table 5.7.28b and Figure 5.7.28a show that of the poor diver skills, operator error was reported as the contributing driver circumstance that resulted in the 2568 vehicle crashes in work zones. Of those crashes less than 1% were fatal, 4% were serious injury 12% were minor injury, 21% were possible injury and 62% were property damage only crashes. Aggressive driving was reported to involve 216 vehicle crashes with 3% fatal, 6% serious injury, 17% minor injury, 17 % possible injury, and 57% property damage only crashes. The combined fatal and serious injury crashes for operator error and aggressive driving were 5% and 9% respectively. This is larger that the 4% of the combined fatal and serious injury crashes for all work zone crashes. The frequency of vehicle crashes involving "operator error" is roughly 25% of all statewide work zone vehicle crashes; whereas, the frequency of vehicle crashes involving "aggressive driving" is roughly 2% of all statewide work zone vehicle crashes.

#29) poor visibility of workers (#veh involved in crash w/ worker)

The visibility of workers is a condition that is very difficult to quantify using the existing vehicle accident report. Therefore, in order to best reflect the seriousness of worker visibility it was determined that a query design made specifically to identify workers involved in work zone crashes would convey the appropriate risk in order to justify the mitigating response to this hazard. Table 5.7.29a shows the database variable that was chosen to represent the hazard of "poor visibility of workers". It was determined that the non-motorist action of "working" was the closest application to the identified hazard. The limitation of this assessment is that it is unknown whether or not the worker was visible. Ultimately this assessment shows that workers are involved in work zone vehicle crashes and the following distributions quantify the extent.

Table 5.7.29a: Database variables used to query "poor visibility of workers"

Assess #	Values Description	Values	Field Name	Field Description
22	Working	3	NM_ACTION	Non-Motorist Action

Table 5.7.29b: Vehicle Crash distribution for "poor visibility of workers"

Assess #	Crash Severity	# Veh. involved	%
22	Fatal	8	20.00%
	Serious Injury	10	25.00%
	Minor Injury	11	27.50%
	Possible Injury	10	25.00%
	Property Damage Only	1	2.50%
	Total	40	

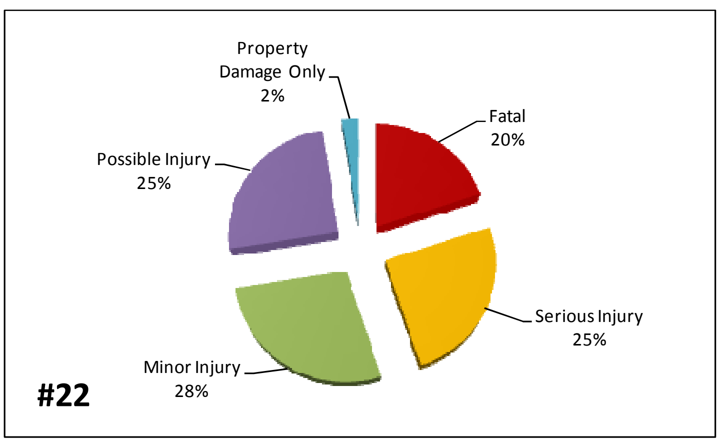


Figure 5.7.29a: Severity distribution for "poor visibility of workers"

Once again this query was designed to determine the number of vehicles involved in crashes where non-motorist action was included in the accident report. Table 5.7.29b and

Figure 5.7.29a show that approximately 40 vehicles were involved in crashes that contained non-motorist action – namely workers present. Of these, 20% were fatal, 25% were serious injury, 28% were minor injury, 25% were possible and 2% was property damage only crashes. The combined fatal and serious injury distribution for this hazard is 45%. This is over ten times the calculated 4% for combined fatal and serious injury crashes of all work zone crashes. Two deaths occurred as a result of the eight vehicles involved in fatal crashes. It should be noted that of the 40 vehicles involved in a crash where a worker was involved, only half of these vehicle crashes were reported to have workers wearing reflective vests. The frequency of vehicle crashes involving a "worker" is roughly 0.4% of all statewide work zone vehicle crashes.

#31) Railroads, pedestrian/bike travel routes & crossings

The statewide crash database for work zones provides a field for road type that directly applies to the hazard of railroads, and pedestrian travel routes and crossings. Table 5.7.31a shows the field names and values descriptions that were used to query the number of vehicles that were involved in crashes in which railroads or pedestrian intersections were described in the crash report. Two separate queries were designed in order to place emphasis on the type of roadway feature that had the greatest impact on the frequency or severity that this hazard had on work zone crashes.

Table 5.7.31a: Database variables used to query "railroads, pedestrian/bike travel routes & crossings"

Assess #	Values Description	Values	Field Name	Field Description
23	Non-intersection: Railroad crossing	3	ROADTYPE	Type of Roadway Junction/Feature
23-b	Intersection: With bike/pedestrian path	21	ROADTYPE	Type of Roadway Junction/Feature

Table 5.7.31b: Vehicle Crash distribution for "railroads, pedestrian/bike travel routes & crossings"

	Assess # 23 Railroad crossing		Assess # 23-b Bike/pedestrian path	
Crash Severity	# Veh. involved	%	# Veh. involved	%
Fatal	2	5.56%	0	0%
Serious Injury	0	0.00%	0	0%
Minor Injury	4	11.11%	0	0%
Possible Injury	8	22.22%	0	0%
Property Damage Only	22	61.11%	0	0%
Total	36	Total	0	

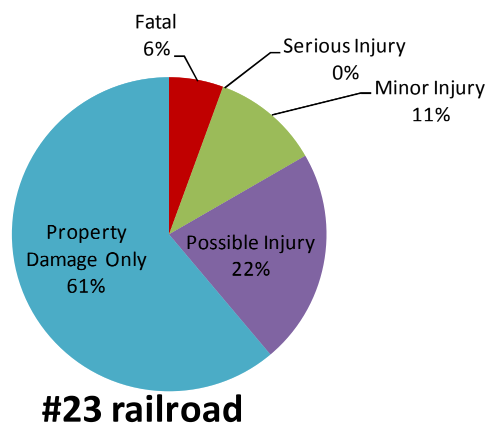


Figure 5.7.31a: Severity distribution for "railroads"

Table 5.7.31b and Figure 5.7.31a show that thirty-six vehicles were involved in crashes in which a non-intersection railroad feature was predominant. Of these crashes, 6% were fatal, none were serious injury, 11% were minor injury, 22% were possible injury, and 61% were property damage only crashes. Combining fatal and serious injury crashes equals 6% of all crashes involving this feature this is larger than the 4% that was calculated for the combined fatal and serious injury crashes of all work zone crashes. Table 5.7.31b also shows that there were no work zone crashes reported from 2001 through October 2008 involving a pedestrian/bike path as a predominant roadway feature. The frequency of vehicle crashes in work zones with a railroad feature is roughly 0.3% of all statewide work zone vehicle crashes.

#32) Road characteristics through the work zone

During the hazard identification process for a typical highway construction project, "road characteristics" were considered a condition that either increases the severity or frequency of a work zone crash. For this hazard, several specific road characteristics or features were lumped together. In the assessment phase, each of the specific characteristics or features were specifically identified and were used to develop the criteria for the query design. In general, the crash database provided fields that directly represented these features specifically; intersections (Table 5.7.32a), roadway ramps (Table 5.7.32b), blind spots or obstructions (Table 5.7.32c), bridges (Table 5.7.32d), and shoulders (Table 5.7.32e). Each of these tables show the data field names, description and values that were used to design each of the queries to identify the number of vehicles that were involved in crashes that occurred in work zones that contained these specific characteristics.

Table 5.7.32a: Database variables used to query "intersections"

Assess #	Values Description	Values	Field Name	Field Description
24	Intersection: Four-way intersection	11	ROADTYPE	Type of Roadway Junction/Feature
	Intersection: T-intersection	12		
	Intersection: Y-intersection	13		
	Intersection: Five leg or more	14		
	Intersection: Offset four-way intersection	15		

Table 5.7.32b: Database variables used to query "ramps"

Assess #	Values Description	Values	Field Name	Field Description
25	Intersection: Intersection with ramp	16	ROADTYPE	Type of Roadway Junction/Feature
	Intersection: On-ramp merge area	17		
	Intersection: Off-ramp diverge area	18		
	Intersection: On-ramp	19		
	Intersection: Off-ramp	20		

Table 5.7.32c: Database variables used to query "blind spot/obscurement"

Assess #	Values Description	Values	Field Name	Field Description
26	Trees/crops	2	VISIONOBS	Vision Obscurement
	Buildings	3		
	Embankment	4		
	Sign/billboard	5		
	Hillcrest	6		
	Parked vehicles	7		
	Moving vehicles	8		

Table 5.7.32c: Database variables used to query "bridge/overpass/underpass"

Assess #	Values Description	Values	Field Name	Field Description
27	Non-intersection: Bridge/overpass/underpass	2	ROADTYPE	Type of Roadway Junction/Feature

Table 5.7.32d: Database variables used to query "shoulders"

Assess #	Values Description	Values	Field Name	Field Description
28	Shoulders (none/low/soft/high)	9	RCONTCIRC	Contributing Circumstance - Roadway

Table 5.7.32e: Vehicle Crash distribution for "road characteristics through the work zone"

	Assess # 24 **intersections**		Assess # 25 **Ramps**		Assess # 27 **bridge/ overpass/underpass**		Assess # 28 **Shoulders (none/low/soft/high)**	
Crash Severity	# Veh. involved	%	# Veh. involving	%	# Veh. involved	%	# Veh. involved	%
Fatal	18	0.79%	12	1.08%	7	0.75%	0	0.00%
Serious Injury	62	2.72%	47	4.22%	29	3.10%	0	0.00%
Minor Injury	215	9.43%	94	8.44%	118	12.62%	2	16.67%
Possible Injury	470	20.62%	215	19.30%	207	22.14%	6	50.00%
Property Damage Only	1514	66.43%	746	66.97%	574	61.39%	4	33.33%
Total	2279	Total	1114	Total	935	Total	12	

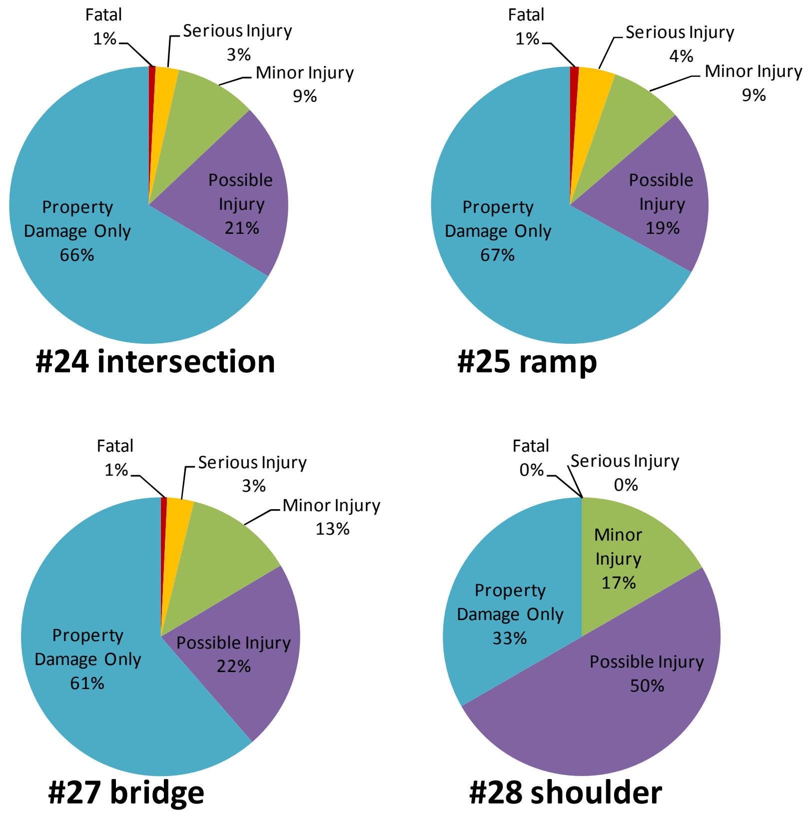


Figure 5.7.32a: Severity distribution for "road characteristics through the work zone"

Table 5.7.32e and Figure 5.7.32a show the statistics for several road characteristics throughout the work zone. Table 5.7.32e groups the road characteristics in terms of specific features of the work zone; intersections, ramps, bridge, and shoulders. As shown, 2279 vehicles were involved in work zone crashes were "intersection" was the predominant junction or feature. Of these 1% were fatal, 3% were serious injury, 9% were minor injury 21% were possible injury, and 66% were property damage only crashes. When ramps were the predominate work zone feature at the crash site, 1114 vehicles were involved in crashes;

of these 1% were fatal, 4% were serious injury, 8% were minor injury, 19% were possible injury, and 67% were property damage only crashes. Nine hundred and thirty-five vehicle crashes occurred in work zones where bridges/overpass/underpass was the predominant feature. Of these, 1% were fatal, 3% were serious injury, 13% were minor injury, 22% were possible injury, and 61% were property damage only crashes. Only 12 vehicle crashes were reported that listed "shoulders" as the contributing circumstance for the roadway. Of these, none were fatal or serious injury, 17% were minor injury, 50% were possible injury, and 33% were property damage only crashes. A combination of fatal and serious injury crashes yield 4% for intersections, 5% for ramps, 4% for bridges, and 0% for shoulders. These are generally similar to the 4% that was calculated for the combined fatal and serious injury crashes of all work zone crashes. The frequency of vehicle crashes in work zones with an "intersection" feature is roughly 22% of all statewide work zone vehicle crashes. The frequency of vehicle crashes in work zones with a "ramp" feature is roughly 11% of all statewide work zone vehicle crashes. The frequency of vehicle crashes in work zones with a "bridge" feature/component is roughly 9% of all statewide work zone vehicle crashes. The frequency of vehicle crashes in work zones with a "shoulder" as a roadway contributing circumstance is roughly 0.1% of all statewide work zone vehicle crashes.

Also included in the hazard "road characteristics through the work zone" are obscurements such as signboards, buildings, crops, parked cars, and the like. Table 5.7.32f and Figure 5.7.32g show that 321 vehicle were involved in crashes where the driver's vision was obscured by such objects. Of these 0% were fatal, 2% were serious injury, 10% were minor injury, 22% were possible injury and 66% were property damage only crashes.

Combining fatal and serious injury crashes yield only 2% which is one half of the 4% that was calculated for the combined fatal and serious injury crashes of all work zone crashes. The frequency of vehicle crashes in work zones where the driver's vision was obscured is roughly 3% of all statewide work zone vehicle crashes.

Table 5.7.32f: Vehicle Crash distribution for "blind spot/obscurement"

Assess #	Crash Severity	# Veh. Involved	%
26	Fatal	0	0.00%
	Serious Injury	7	2.18%
	Minor Injury	33	10.28%
	Possible Injury	70	21.81%
	Property Damage Only	211	65.73%
	Total	321	

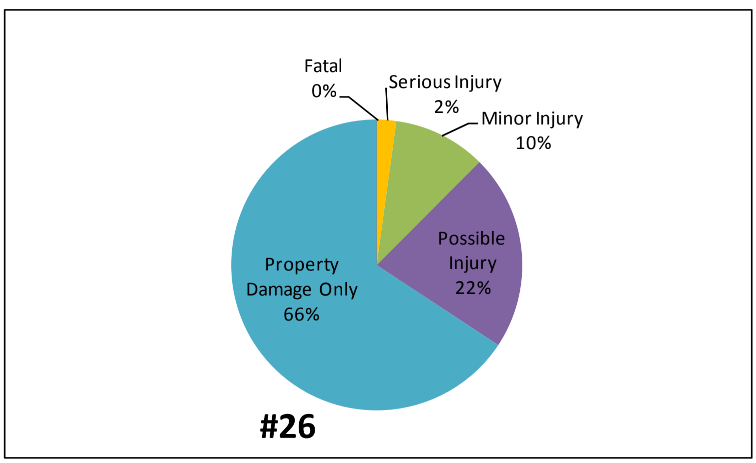


Figure 5.7.32g: Severity distribution for "blind spot/obscurement"

#33) The condition of roadway (road surface condition/debris /ruts/holes/bumps/worn surface)

The “condition of the roadway” was identified as hazard that could contribute to the frequency or severity of work zone crashes. Table 5.7.33a shows the field that was used in the query design to extract crash data that directly related to the roadway condition. No additional assumptions were necessary to assess this hazard since the accident report allowed the investigating officer to enter an appropriate roadway contributing circumstance to the crash.

Table 5.7.33a: Database variables used to query “the condition of roadway”

Assess #	Values Description	Values	Field Name	Field Description
29	Road surface condition	2	RCONTCIRC	Contributing Circumstance - Roadway
	Debris	3		
	Ruts/holes/bumps	4		
	Worn/travel-polished surface	6		

Table 5.7.33b: Vehicle Crash distribution for “the condition of roadway”

Assess #	Crash Severity	# Veh. Involved	%
29	Fatal	3	1.54%
	Serious Injury	3	1.54%
	Minor Injury	23	11.79%
	Possible Injury	46	23.59%
	Property Damage Only	120	61.54%
	Total	195	

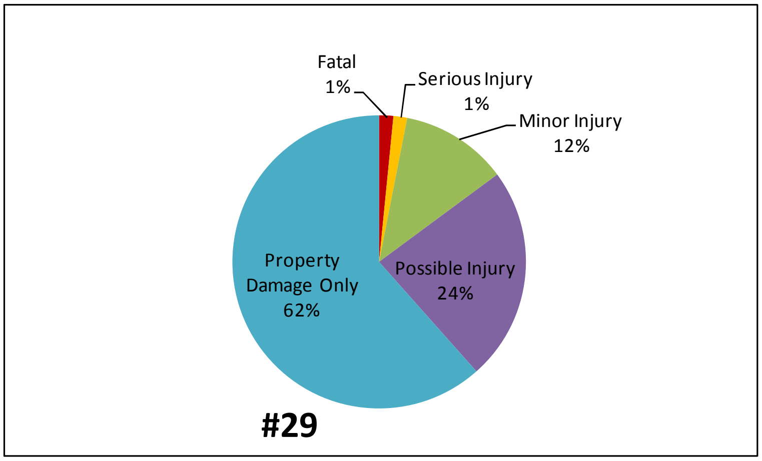


Figure 5.7.33a: Severity distribution for "the condition of roadway"

Table 5.7.33b and Figure 5.7.33a show that 195 vehicles were involved in crashes where "the condition of the roadway" was reported as a contributing circumstance. Of these, 2% were fatal, 2% were serious injury, 12% were minor injury, 24% were possible injury, and 62% were property damage only crashes. Combining fatal and serious injury crashes equals 4% of all vehicle crashes where "the condition of the roadway" was considered a contributing circumstance. This is equal to the 4% that was calculated for the combined fatal and serious injury crashes of all work zone crashes. The frequency of these vehicle crashes is roughly 2% of all statewide work zone vehicle crashes.

#34) The points of merge (between advance warning & work area; within transition area for lane shift)

During the focus group discussion, “the points of merge” were identified as a hazard that could either increase the likelihood or severity of a work zone crash. Fortunately, the statewide crash data provided a field that allowed for database query to directly extract crash information that pertains to the location of the crash within the work zone. Table 5.7.34a shows the values and value descriptions that were used in this research as a means to assess the points of merge within a highway work zone.

Table 5.7.34a: Database variables used to query “the points of merge”

Assess #	Values Description	Values	Field Name	Field Description
30	Between advance warning sign and work area	2	WZ_LOC	Location
	Within transition area for lane shift	3		

Table 5.7.34b: Vehicle Crash distribution for “the points of merge”

Assess #	Crash Severity	# Veh. involved	%
30	Fatal	29	0.87%
	Serious Injury	132	3.96%
	Minor Injury	391	11.74%
	Possible Injury	655	19.67%
	Property Damage Only	2123	63.75%
	Total	3330	

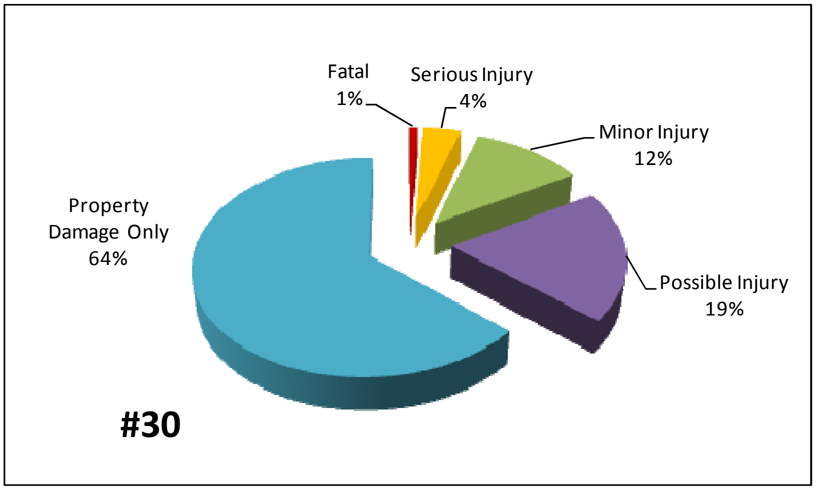


Figure 5.7.34a: Severity distribution for "the points of merge"

Table 5.7.34b and Figure 5.7.34a show that 3330 vehicles were involved in crashes that were reported to be located in the merge areas of the work zone. Of these crashes 1% were fatal, 4% were serious injury, 12% were minor injury, 19% were possible injury, and 64% were property damage only crashes. The combination of fatal and serious injury crashes within the points of merge of the work zone was approximately 5% of total of these crashes. This is slightly larger than the 4% of the combined fatal and serious injury crashes for all work zone crashes. The frequency of vehicle crashes within "the points of merge" is roughly 32% of all statewide work zone vehicle crashes.

#35) The posted speed through the work zone

The posted speed has been identified as a hazard in highway work zones. Fortunately the statewide crash data provides information regarding the posted speed limit of the crash location. Table 5.7.35a contains the variable that was used to design the queries used to extract crash data for bracketed speed data. The bracketing of speed limits are similar to those bracketed by the Kansas Work Zone Analysis by Dr. Young Bai (2008). The bracketed speed limits were 65 mph and larger, 55 to 60 mph, 40 to 50 mph, 30 to 35 mph, and 25 mph and lower posted speed limits. Queries were designed to provide data for assessment number 31 to 35.

Table 5.7.35a: Database variables used to query "the posted speed"

Assess #	Values Description	Values	Field Name	Field Description
31	65 mph posted speed limit	65	SPEEDLIMIT	Speed Limit
32	55 – 60 mph posted speed limit	60 55	SPEEDLIMIT	Speed Limit
33	40 – 50 mph posted speed limit	50 45 40	SPEEDLIMIT	Speed Limit
34	30 – 35 mph posted speed limit	35 30	SPEEDLIMIT	Speed Limit
35	25 mph (and lower) posted speed limit	25 20 15 10 5	SPEEDLIMIT	Speed Limit

Table 5.7.35b: Vehicle Crash distribution for “the posted speed”

	Assess # 31 65(+) mph		Assess # 32 55 to 60 mph		Assess # 33 40 to 50 mph		Assess # 34 30 to 35 mph		Assess # 35 25(-) Mph	
Crash Severity	# Veh.	%	# Veh.	%	# Veh.	%	# Veh.	%	# Veh.	%
Fatal	18	2.83%	48	1.27%	3	0.20%	10	0.37%	8	0.56%
Serious Injury	50	7.87%	199	5.25%	46	3.10%	56	2.05%	16	1.11%
Minor Injury	83	13.07%	490	12.92%	159	10.70%	248	9.09%	109	7.57%
Possible Injury	114	17.95%	741	19.54%	376	25.30%	621	22.76%	235	16.32%
Property Damage Only	370	58.27%	2314	61.02%	902	60.70%	1793	65.73%	1072	74.44%
Total	635	Total	3792	Total	1486	Total	2728	Total	1440	

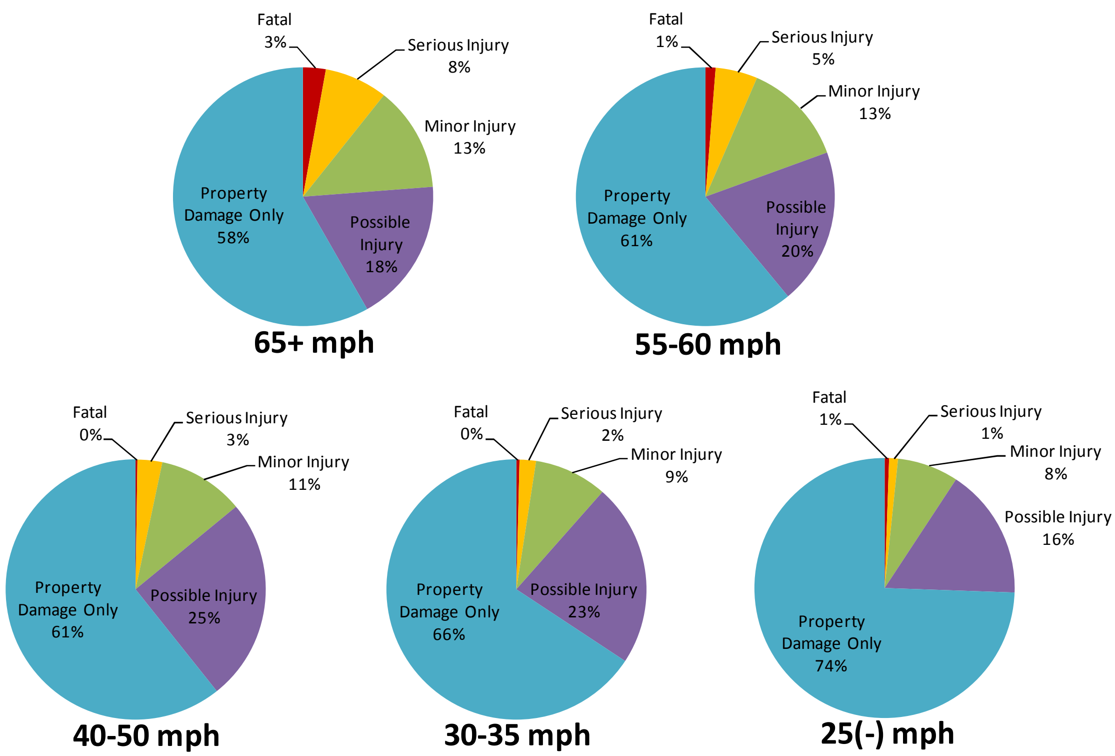


Figure 5.7.35a: Severity distribution for “the posted speed (mph)”

Table 5.7.35b and Figure 5.7.35a show that 635 vehicles were involved in work zone crashes with a posted speed of 65 mph. Of these 3% were fatal, 8% were serious injury, 13% were minor injury, 18% were possible injury, and 58% were property damage only crashes. Table 5.7.35b and Figure 5.7.35a show that 3792 vehicles were involved in work zone crashes with a posted speed between 55 and 60 mph. Of these 1% were fatal, 5% were serious injury, 13% were minor injury, 20% were possible injury, and 61% were property damage only crashes. Table 5.7.35b and Figure 5.7.35a show that 1486 vehicles were involved in work zone crashes with a posted speed between 40 and 50 mph. Of these 0% were fatal, 3% were serious injury, 11% were minor injury, 25% were possible injury, and 61% were property damage only crashes. Table 5.7.35b and Figure 5.7.35a show that 2728 vehicles were involved in work zone crashes with a posted speed between 30 and 35 mph. Of these 0% were fatal, 2% were serious injury, 9% were minor injury, 23% were possible injury, and 66% were property damage only crashes. Table 5.7.35b and Figure 5.7.35a show that 1440 vehicles were involved in work zone crashes with a posted speed 25mph and below. Of these 1% were fatal, 1% were serious injury, 8% were minor injury, 16% were possible injury, and 74% were property damage only crashes.

The combination of fatal and serious injury crashes within work zones with a posted speed of 65 mph or greater is approximately 11% of total of these crashes. This is nearly three times the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes within work zones with a posted speed between 55 and 60 mph is approximately 6% of total of these crashes. This is greater than the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes within work zones with a posted speed between 40 and 50 mph is approximately 3% of total of these crashes. This is slightly smaller than the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes within work zones with a posted speed between 30 and 35 mph is approximately 2% of total of these crashes. This is half the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes within work zones with a posted speed of 25 mph or lower is approximately 2% of total of these crashes. This also is half the 4% of the combined fatal and serious injury crashes for all work zone crashes.

The frequency of vehicle crashes with posted speed limit of 65 mph and greater is roughly 6% of all statewide work zone vehicle crashes. The frequency of vehicle crashes with posted speed limit between 55 and 60 mph is roughly 37% of all statewide work zone vehicle crashes. The frequency of vehicle crashes with posted speed limit between 40 and 50 mph is roughly 14% of all statewide work zone vehicle crashes. The frequency of vehicle crashes with posted speed limit between 30 and 35 mph is roughly 26% of all statewide work zone vehicle crashes. The frequency of vehicle crashes with posted speed limit of 25 mph and below is roughly 14% of all statewide work zone vehicle crashes.

#38) Traffic congestion & delay through the work zone (assumes stop-and-go traffic conditions)

Traffic congestion and delay through the work zone is a hazard that is most difficult to quantify using statewide crash data. Since there are no fields in the investigating officer's report for the traffic condition, assumptions must be made as to the contributing circumstances of the driver and the sequence of events that leads to work zone crashes. For this hazard it was assumed that since most traffic congestion results in stop-and-go traffic conditions where avoidance and evasive actions are routine driver response to heavy traffic. Table 5.7.38a shows the variables and the corresponding field descriptions that were used to design the query that was used to extract data that best reflected "traffic congestion and delay" conditions within the work zone.

Table 5.7.38a: Database variables used to query "traffic congestion & delay"

Assess #	Values Description	Values	Field Name	Field Description
36	Swerved to avoid: vehicle/object/non-motorist/or animal in roadway	10	DCONTCIRC1	Contributing Circumstance - Driver
	Evasive action (swerve, panic braking, etc.)	6	SEQEVENTS1	Sequence of Event 1st Event

Table 5.7.38b and Figure 5.7.38a show that 730 vehicles were involved in work zone crashes where evasive action or avoidance maneuvers were utilized by the driver(s)/operators. Of these 1% were fatal, 5% were serious injury, 13% were minor injury, 18% were possible injury, and 63% were property damage only crashes. The combination of fatal and serious injury crashes where evasive action or avoidance maneuvers were utilized

by the driver/operators is approximately 6% of total of the crashes. This is larger than the 4% of the combined fatal and serious injury crashes for all work zone crashes. The frequency of vehicle crashes with "evasive action or avoidance maneuvers" is roughly 7% of all statewide work zone vehicle crashes.

Table 5.7.38b: Vehicle Crash distribution for "traffic congestion & delay"

Assess #	Crash Severity	# Veh. involved	%
36	Fatal	5	0.68%
	Serious Injury	38	5.21%
	Minor Injury	93	12.74%
	Possible Injury	131	17.95%
	Property Damage Only	463	63.42%
	Total	730	

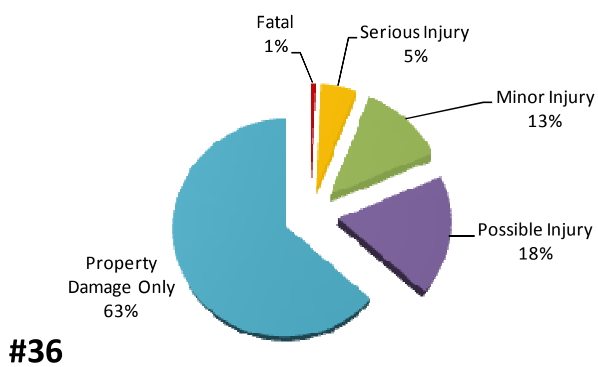


Figure 5.7.38a: Severity distribution for "traffic congestion & delay"

#39) Traffic speed & speeding (exceeded authorized speed)

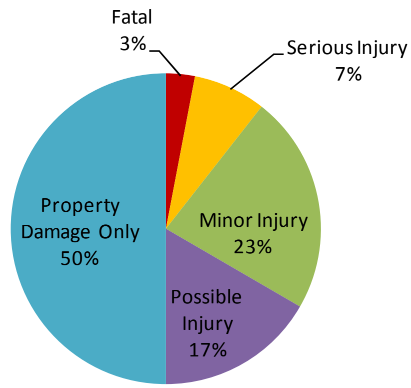
Speeding has been identified as a work zone hazard. Fortunately the statewide crash database provides a field that recognizes driver contributing circumstances of "exceeded authorized speed." This allows the researcher to directly apply the crash data to this hazard without making any additional assumptions or assertions. Table 5.7.39a contains the field information, values, and values description that was utilized in order to design the query that extracted the crash data pertaining to this hazard.

Table 5.7.39a: Database variables used to query "speeding"

Assess #	Values Description	Values	Field Name	Field Description
37	Exceeded authorized speed	3	DCONTCIRC1	Contributing Circumstance - Driver

Table 5.7.39b: Vehicle Crash distribution for "speeding"

Assess #	Crash Severity	# Veh. involved	%
37	Fatal	2	3.03%
	Serious Injury	5	7.58%
	Minor Injury	15	22.73%
	Possible Injury	11	16.67%
	Property Damage Only	33	50.00%
	Total	66	



#37

Figure 5.7.39a: Severity distribution for "speeding"

Table 5.7.39b and Figure 5.7.39a show that 66 vehicles were involved in crashes where "speeding" was cited as a driver contributing circumstance. Of these 3% were fatal, 7% were serious injury, 23% were minor injury, 17% were possible injury, and 50% were property damage only crashes. The combination of fatal and serious injury crashes where "speeding" was cited is approximately 10% of total of the crashes. This is more than two and a half times the 4% of the combined fatal and serious injury crashes for all work zone crashes. The frequency of vehicle crashes where the driver was cited for "speeding" is roughly 0.6% of all statewide work zone vehicle crashes.

#12) High risk traffic – Day of the week

"High risk traffic" was the term given to the hazards associated with the construction schedule. This means that days of the week, specifically Fridays and Saturdays were identified as a work zone hazard. In order to get a feel for the effect that the day of the week has on work zone crashes, an assessment was made of the crash data for each day of the week in order to determine which day was associated with the greatest risk in work zones. Table 5.7.12a shows the values and field descriptions that were used to design the queries that were used to extract crash data for each day of the week. A separate assessment was performed on each day.

Table 5.7.12a: Database variables used to query "day of the week"

Assess #	Values Description	Values	Field Name	Field Description
38	Sunday	1	DAY	Day of week
39	Monday	2	DAY	Day of week
40	Tuesday	3	DAY	Day of week
41	Wednesday	4	DAY	Day of week
42	Thursday	5	DAY	Day of week
43	Friday	6	DAY	Day of week
44	Saturday	7	DAY	Day of week

Table 5.7.12b and Figure 5.7.12a show that 671 vehicle crashes occurred on "Sundays" where 1% were fatal, 6% were serious injury, 15% were minor injury, 21% were possible, and 57% were property damage only crashes. These tables and figures show that 1572 vehicle crashes occurred on "Mondays" where 0% were fatal, 2% were serious injury, 10% were minor injury, 22% were possible, and 65% were property damage only crashes. In addition, 1706 vehicle crashes occurred on "Tuesdays" where 0% were fatal, 4% were serious injury, 10% were minor injury, 18% were possible, and 67% were property damage only crashes. Similarly, 1773 vehicle crashes occurred on "Wednesdays" where 1% were fatal, 3% were serious injury, 11% were minor injury, 22% were possible, and 63% were

property damage only crashes. These tables and figures show that 1819 vehicle crashes occurred on “Thursdays” where 1% were fatal, 3% were serious injury, 9% were minor injury, 19% were possible, and 68% were property damage only crashes. One thousand eight hundred and forty three vehicle crashes occurred on “Fridays” where 1% were fatal, 4% were serious injury, 12% were minor injury, 22% were possible, and 62% were property damage only crashes. In addition, 981 vehicle crashes occurred on “Saturdays” of which 1% were fatal, 4% were serious injury, 9% were minor injury, 22% were possible, and 64% were property damage only crashes.

Table 5.7.12b: Vehicle Crash distribution for “day of the week”

		CRASH SEVERITY					
		Fatal	Serious Injury	Minor Injury	Possible Injury	Property Damage Only	TOTAL
Assess #38 SUN	# Veh. involved	7	37	104	139	384	671
	%	1.04%	5.51%	15.50%	20.72%	57.23%	
Assess #39 MON	# Veh. involved	6	36	162	344	1024	1572
	%	0.38%	2.29%	10.31%	21.88%	65.14%	
Assess #40 TUE	# Veh. involved	8	69	173	311	1145	1706
	%	0.47%	4.04%	10.14%	18.23%	67.12%	
Assess #41 WED	# Veh. involved	15	60	190	385	1123	1773
	%	0.85%	3.38%	10.72%	21.71%	63.34%	
Assess #42 THU	# Veh. involved	21	48	171	341	1238	1819
	%	1.15%	2.64%	9.40%	18.75%	68.06%	
Assess #43 FRI	# Veh. involved	22	74	215	397	1135	1843
	%	1.19%	4.02%	11.67%	21.54%	61.58%	
Assess #44 SAT	# Veh. involved	14	40	86	218	623	981
	%	1.43%	4.08%	8.77%	22.22%	63.51%	

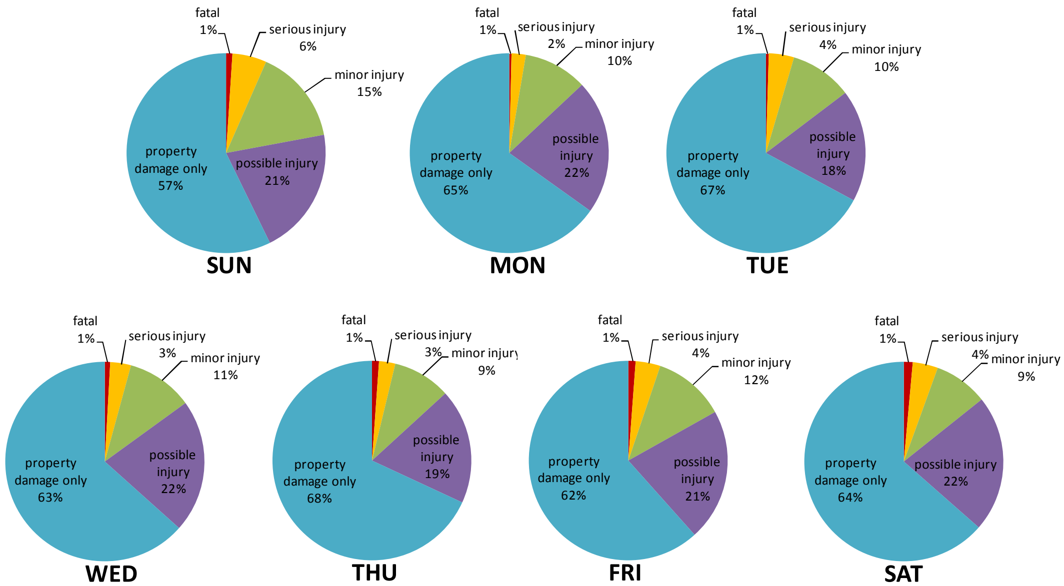


Figure 5.7.12a: Severity distribution for “day of the week”

The combination of fatal and serious injury crashes on “Sundays” is approximately 7% of total of the Sunday crashes. This is nearly twice the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes on “Mondays” is approximately 2% of total of the Monday crashes. This is half the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes on “Tuesdays” is approximately 4% of total of the Tuesday crashes. This is the same as the 4% of the combined fatal and serious injury crashes for all work zone crashes. Likewise, the combination of fatal and serious injury crashes on “Wednesdays” is approximately 4% of total of the Wednesday crashes. This is equal to the 4% of the combined fatal and serious injury crashes for all work zone crashes. Also, the combination of fatal and serious injury crashes on “Thursday” is approximately 4% of total of the Thursday crashes. This is the same as the 4% of the combined fatal and serious injury crashes for all work zone crashes. However, the combination of fatal and serious injury crashes on “Fridays” is approximately 5% of total of the Friday crashes. This is greater than the 4% of the combined fatal and serious injury crashes for all work zone crashes. Similarly, the combination of fatal and serious injury crashes on “Saturdays” is approximately 5% of total of the Saturday crashes. This is slightly larger than the 4% of the combined fatal and serious injury crashes for all work zone crashes as well.

The frequency of vehicle crashes on “Sundays” is roughly 6% of all statewide work zone vehicle crashes. The frequency of vehicle crashes on “Mondays” is roughly 15% of all statewide work zone vehicle crashes. The frequency of vehicle crashes on “Tuesdays” is roughly 16% of all statewide work zone vehicle crashes. The frequency of vehicle crashes on “Wednesdays” is roughly 17% of all statewide work zone vehicle crashes. The frequency of vehicle crashes on “Thursdays” is roughly 18% of all statewide work zone vehicle crashes. The frequency of vehicle crashes on “Fridays” is roughly 18% of all statewide work zone vehicle crashes. The frequency of vehicle crashes on “Saturdays” is roughly 10% of all statewide work zone vehicle crashes.

#10) Extra traffic volume through work zone from: seasonal traffic /road use

The method chosen as the most effective means of assessing the extra traffic volume through the work zone from seasonal traffic or road use was to assess the crash data for each month of the year. This was accomplished through the design of queries that extracted crash data from each month of the year from the statewide crash database. Queries were used to build a data set for each month. Table 5.7.10a shows the field name and description of values that were used for each assessment.

Table 5.7.10a: Database variables used to query "seasonal traffic /road use"

Assess #	Values Description	Values	Field Name	Field Description
45	January	1	MONTH	Month
46	February	2	MONTH	Month
47	March	3	MONTH	Month
48	April	4	MONTH	Month
49	May	5	MONTH	Month
50	June	6	MONTH	Month
51	July	7	MONTH	Month
52	August	8	MONTH	Month
53	September	9	MONTH	Month
54	October	10	MONTH	Month
55	November	11	MONTH	Month
56	December	12	MONTH	Month

Table 5.7.10b and Figure 5.7.10a show that 189 vehicle crashes occurred in "January" where 1% were fatal, 2% were serious injury, 11% were minor injury, 15% were possible, and 71% were property damage only crashes. The tables and figures show that 204 vehicle crashes occurred in "February" where 1% were fatal, 1% were serious injury, 6% were minor injury, 21% were possible, and 71% were property damage only crashes. In "March" 263 vehicle crashes occurred in which 0% were fatal, 4% were serious injury, 12% were minor injury, 17% were possible, and 67% were property damage only crashes. Seven hundred and

sixty four vehicle crashes occurred in "April" where 0% were fatal, 6% were serious injury, 9% were minor injury, 18% were possible, and 68% were property damage only crashes. The tables and figures show that 1069 vehicle crashes occurred in "May" where 1% were fatal, 3% were serious injury, 11% were minor injury, 19% were possible, and 66% were property damage only crashes. In increase is shown on the tables and figures as 1324 vehicle crashes occurred in "June" where 2% were fatal, 4% were serious injury, 11% were minor injury, 21% were possible, and 62% were property damage only crashes. The tables and figures show that 1396 vehicle crashes occurred in "July" where 1% were fatal, 4% were serious injury, 11% were minor injury, 21% were possible, and 63% were property damage only crashes. Again, for the month of August, the tables and figures show that 1407 vehicle crashes occurred where 1% were fatal, 2% were serious injury, 12% were minor injury, 20% were possible, and 65% were property damage only crashes. The tables and figures show that 1474 vehicle crashes occurred in "September" where 2% were fatal, 4% were serious injury, 10% were minor injury, 22% were possible, and 62% were property damage only crashes. Twelve hundred and eighty two vehicle crashes occurred in "October" where 0% were fatal, 3% were serious injury, 11% were minor injury, 23% were possible, and 63% were property damage only crashes. The tables and figures show that 749 vehicle crashes occurred in "November" where 2% were fatal, 2% were serious injury, 11% were minor injury, 21% were possible, and 64% were property damage only crashes. And finally, 250 vehicle crashes were shown to have occurred in "December" where 0% were fatal, 7% were serious injury, 10% were minor injury, 18% were possible, and 65% were property damage only crashes.

Table 5.7.10b: Vehicle Crash distribution for "seasonal traffic /road use"

		CRASH SEVERITY					
		Fatal	Serious Injury	Minor Injury	Possible Injury	Property Damage Only	TOTAL
Assess #45 JAN	# Veh. involved	2	4	21	28	134	189
	%	1.06%	2.12%	11.11%	14.81%	70.90%	
Assess #46 FEB	# Veh. involved	2	2	12	43	145	204
	%	0.98%	0.98%	5.88%	21.08%	71.08%	
Assess #47 MAR	# Veh. involved	0	10	31	45	177	263
	%	0.00%	3.80%	11.79%	17.11%	67.30%	
Assess #48 APR	# Veh. involved	2	44	67	135	516	764
	%	0.26%	5.76%	8.77%	17.67%	67.54%	
Assess #49 MAY	# Veh. involved	6	35	113	208	707	1069
	%	0.56%	3.27%	10.57%	19.46%	66.14%	
Assess #50 JUN	# Veh. involved	22	54	143	278	827	1324
	%	1.66%	4.08%	10.80%	21.00%	62.46%	
Assess #51 JUL	# Veh. involved	9	57	158	287	885	1396
	%	0.64%	4.08%	11.32%	20.56%	63.40%	
Assess #52 AUG	# Veh. involved	8	34	162	288	915	1407
	%	0.57%	2.42%	11.51%	20.47%	65.03%	
Assess #53 SEP	# Veh. involved	24	61	153	323	913	1474
	%	1.63%	4.14%	10.38%	21.91%	61.94%	
Assess #54 OCT	# Veh. involved	6	36	136	294	810	1282
	%	0.47%	2.81%	10.61%	22.93%	63.18%	
Assess #55 NOV	# Veh. involved	12	14	80	160	483	749
	%	1.60%	1.87%	10.68%	21.36%	64.49%	
Assess #56 DEC	# Veh. involved	0	17	25	46	162	250
	%	0.00%	6.80%	10.00%	18.40%	64.80%	

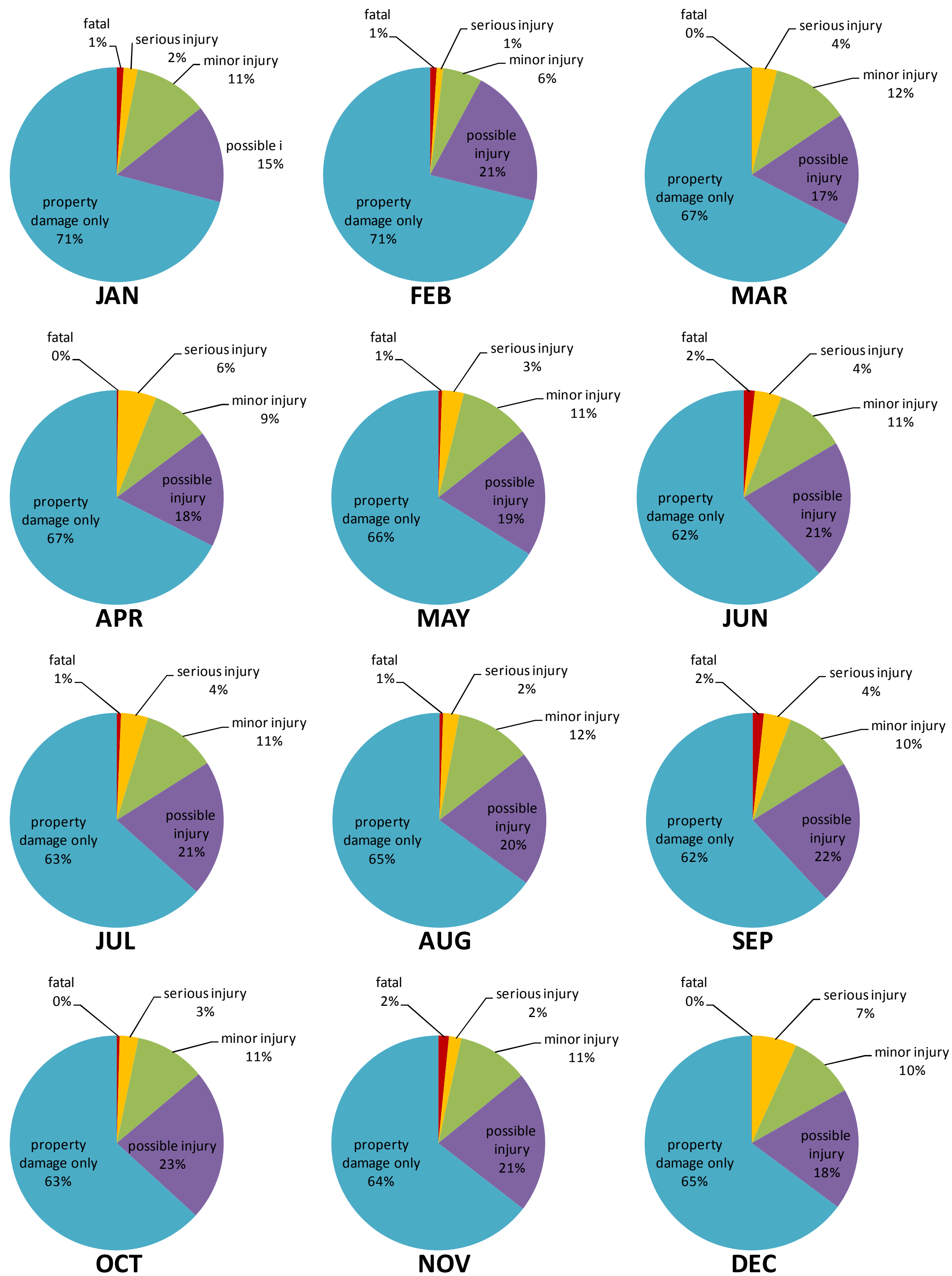


Figure 5.7.10a: Severity distribution for "seasonal traffic /road use"

The combination of fatal and serious injury crashes in “January” is approximately 3% of total of the January crashes. This is slightly less than the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes in “February” is approximately 2% of total of the February crashes. This is half the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes in “March” is approximately 4% of total of the March crashes. This is equal to the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes increases in “April” to approximately 6% of total of the April crashes. This is greater than the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes in “May” is approximately 4% of total of the May crashes. This is the same as the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes in “June” is approximately 6% of total of the June crashes. This is greater than the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes in “July” is approximately 5% of total of the July crashes. This is slightly larger than the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes in “August” is approximately 3% of total of the August crashes. This is slightly less than the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes in “September” is approximately 6% of total of the September crashes. This is greater than the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes in “October” is approximately 3% of total of the October crashes.

This is slightly less than the 4% of the combined fatal and serious injury crashes for all work zone crashes. The combination of fatal and serious injury crashes in “November” is approximately 4% of total of the November crashes. This is nearly equal to the 4% of the combined fatal and serious injury crashes for all work zone crashes. And the combination of fatal and serious injury crashes in “December” is approximately 7% of total of the December crashes. This is nearly twice the 4% of the combined fatal and serious injury crashes for all work zone crashes.

The frequency of vehicle crashes typically in “January” is roughly 2% of all statewide work zone vehicle crashes. The frequency of vehicle crashes typically in “February” is roughly 2% of all statewide work zone vehicle crashes. The frequency of vehicle crashes typically in “March” is roughly 3% of all statewide work zone vehicle crashes. The frequency of vehicle crashes typically in “April” is roughly 7% of all statewide work zone vehicle crashes. In “May” the frequency of vehicle crashes is roughly 10% of all statewide work zone vehicle crashes. The frequency of vehicle crashes typically in “June” is roughly 13% of all statewide work zone vehicle crashes. Similarly, the frequency of vehicle crashes typically in “July” is roughly 13% of all statewide work zone vehicle crashes. The frequency of vehicle crashes typically in “August” is roughly 14% of all statewide work zone vehicle crashes. For “September” the frequency of vehicle crashes is roughly 14% of all statewide work zone vehicle crashes. The frequency of vehicle crashes typically in “October” is roughly 12% of all statewide work zone vehicle crashes. By November, the frequency of vehicle crashes is roughly 7% of all statewide work zone vehicle crashes. The frequency of vehicle crashes typically in “December” is roughly 2% of all statewide work zone vehicle crashes.

5.4 RISK ASSESSMENT

The risk assessment tool created from this work is intended to provide a quasi-quantitative guide to risk assessments based on quantitative data provided from a statewide crash database. In the previous section, the statewide crash data base was queried in order to provide descriptive statistics of crashes that possessed characteristics similar to the hazards identified in part one of this chapter. The purpose of the descriptive statistics was to evaluate the severity and frequency of vehicle crashes with specific characteristics. In this section, the severity and frequency of those crashes will be “normalized” against all statewide work zone crashes in order to get a relative comparison of crash severity and frequency that a particular hazard poses on a work zone.

The tool that was chosen to best apply to a qualitative assessment of work zone hazards is the risk matrix (Figure 5.8.0). The risk matrix is a two dimensional representation of frequency and severity of crashes with specific characteristics (hazards) that are associated with the crash.

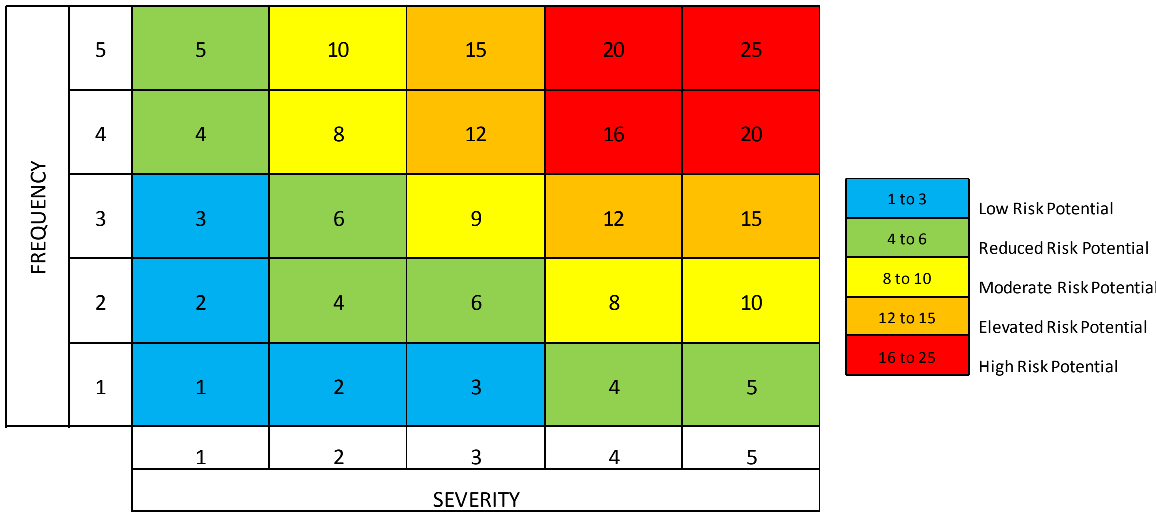


Figure 5.8.0 – Risk Assessment Matrix

This section will develop a process that converts the frequency and severity of crashes with characteristics that best reflect the identified hazards in the first phase of this research in order to rank the relative importance of each work zone hazard. In the subsequent sections, the frequency and severity of the crashes will be "normalized" in order to ascertain the relative severity distribution of each hazard with respect to the severity distribution of all work zone crashes. This is accomplished through the formulation of an average crash severity ratio and then ranking that ratio on a scale from one to five as shown on the horizontal axis of the risk assessment matrix. The relative frequency of the vehicle crashes with characteristics that best reflect each identified hazard was developed by dividing the total number of crashes that best represent that hazard by the sum of all statewide work zone crashes included in this study from the crash database. The relative frequency was then plotted on a scale from one to five as shown on the vertical axis of the risk assessment matrix. The following sections will delve deeper into the development of this assessment method.

5.4.1 Bracketing for Severity and Frequency Ranking Scales

In order to determine the brackets for each of the five rankings for severity and frequency of vehicle crashes, a normalized frequency distribution of the observations were made. In the case of both the frequencies and severities calculated in this research, the data required a transformation due to its non-normal distribution. Although many transformations may be applied to the data, the common logarithm based 10 (Log_{10}) provided the "best" representation of a normally distributed data set (Devore, 2000; Berenson, 2006). The transformed standard deviation was utilized to divide the distribution into five segments. Segments ranging from 1 to 5 were established to correspond to one standard deviation from the mean, with the center segment including one half of a standard deviation on either side of the mean. This means that rank number three includes all values one half of a standard deviation above and below the mean. Rank number two includes values that were between one and a half standard deviations and one half standard deviations below the mean. Rank number four included values that were between one and a half standard deviations and one half standard deviations above the mean. The rank of one and five were less than one and a half and greater than one and a half standard deviations from the mean, respectively (see Figure 5.8.1 and Table 5.8.1 for bracketing information).

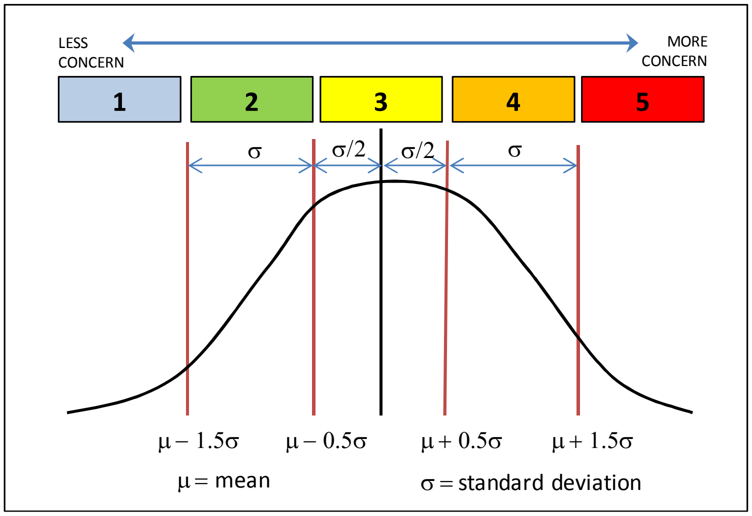


Figure 5.8.1 Ranking Brackets for Hazard Severity and Frequency

Table 5.8.1 Ranking Brackets for Hazard Severity and Frequency

RANKING SCALES	RANKING BRACKETS
5	$\mu + 1.5\sigma \leq X_k$
4	$\mu + 0.5\sigma \leq X_k < \mu + 1.5\sigma$
3	$\mu - 0.5\sigma \leq X_k < \mu + 0.5\sigma$
2	$\mu - 1.5\sigma \leq X_k < \mu - 0.5\sigma$
1	$X_k < \mu - 1.5\sigma$

Utilizing the normal probability density function (Equation 5.8.1a), the probabilities of crashes with varying ranks from one to five can be determined. The transformation formula (Equation 5.8.1b) and the standardized normal probability density function can be utilized to determine the probability of a crash with a crash severity ratio that falls within the limits of each of the five severity rankings.

Equation 5.8.1a: Normal Probability Density Function:

$$f(X) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\left(\frac{1}{2}\right)\left[\frac{X-\mu}{\sigma}\right]^2}$$

Equation 5.8.1b: Transformation Formula:

$$Z = \frac{X - \mu}{\sigma}$$

Equation 5.8.1c: Standardized Normal Probability Density Function:

$$f(Z) = \frac{1}{\sqrt{2\pi}} e^{-\left(\frac{1}{2}\right)Z^2}$$

Equation 5.8.1d: Mean:

Equation 5.8.1e: Standard Deviation:

Where; μ = mean of the sample of either average severity ratio or relative frequency for all hazard/assessments; σ = standard deviation of the sample of either average severity ratio or relative frequency for all hazard/assessments; k= ordinal number of each hazard/assessment number (1 to 56); N= total number of hazard/assessments (56); and X_k= any value of a continuous variable representing either average relative severity ratio (SR_k^{avg}) or relative frequency (RF_k) for hazard/assessment k.

When the ranking brackets are defined by the number of standard deviations from the mean, the determination of probabilities can be made. For the rank of one (values that are one and a half standard deviations below the mean), the probability of a value falling in that category is approximately 7%. For the rank of two (values that are between one and a half standard deviations and one half standard deviations below the mean), the probability of a value falling in that category is approximately 24%. The rank number of three (values between one half of a standard deviation above and below the mean),indicates the probability of a value falling in that category is approximately 38%. For there rank number of four (values that fall between one half standard deviations and one and a half standard deviations above the mean), the probability of a value falling in that rank is 24%. Finally, for the rank of five (values greater than one and a half standard deviations from the mean), the probability of a value falling is that category is 7%.

5.4.2 Crash Severity Ratio

The crash severity ratio was developed in order to determine the relative severity distribution of work zone crashes with characteristics similar to the identified work zone hazard with respect to the severity distribution of all work zone hazards. In the previous sections it was shown that the severity distribution of all vehicles involved in work zone crashes from 2001 through October 2008 were as follows: 0.90% were fatal, 3.55% were serious injury, 10.62% were minor injury, 20.59% were possible injury, and 64.35% were property damage only crashes. For this research, a “typical” crash is considered to have such a severity distribution.

A crash severity ratio was developed as a product of this research that calculates the severity ratio for a particular identified hazard with respect to the severity of a “typical” work zone crash. For each assessed hazard, the ratio is calculated by first summing the number of vehicle crashes in each of the five severity levels (where 1=fatality; 2=serious injury; 3= minor injury; 4= possible injury; and 5=property damage only) for each of the eight years (2001-2008) of data included in the assessment. For each hazard category, a percentage is determined by dividing the crashes in each severity level by the total vehicle crashes in that category. The severity ratio is then determined by dividing the percentage of vehicle crashes at each severity level for a particular hazard by the percentage of all vehicle crashes ("typical crash") for that specific severity level. The operation is expressed in the following equation.

Equation 5.8.2: Severity ratio equation:

$$SR_{ik} = \frac{\sum_{j=1}^{8} v_{ijk} \sum_{i=1}^{5} \sum_{j=1}^{8} w_{ij}}{\sum_{j=1}^{8} w_{ij} \sum_{i=1}^{5} \sum_{j=1}^{8} v_{ijk}}$$

Where: SR_{ik} = severity ratio of severity level *i* for hazard/assessment *k*; v_{ijk} = number of vehicles involved in a crash with severity *i* for year *j*, from hazard/assessment # *k*; w_{ijk} = number of vehicles involved in a crash with severity *i* for year *j*, for all work zone crashes; *i*= ordinal number of risk severity from 1 to 5 (where 1=fatality; 2=serious injury; 3= minor injury; 4= possible injury; and 5=property damage only); *j*= ordinal number of database year from 1 to 8 where 1=2001, and 8=2008

Severity and Frequency of crashes (total # of vehicles involved)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%
1	23	17	9	11	11	2	7	13	1	93	0.90%
2	18	52	39	68	52	46	46	47	2	368	3.55%
3	96	174	130	150	178	166	88	119	3	1101	10.62%
4	157	250	294	306	347	308	210	263	4	2135	20.59%
5	416	663	988	1141	998	908	795	763	5	6672	64.35%
total	710	1156	1460	1676	1586	1430	1146	1205	total	10369	
query:	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9								

1 #3) build/rebuild under traffic (#vehicles) - work on shoulder

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	3	0	3	3	0	0	3	0	1	12	0.79%	0.9	0.8
2	0	6	4	8	6	2	4	5	2	35	2.31%	0.7	
3	22	10	13	15	29	27	16	13	3	145	9.58%	0.9	
4	38	50	45	74	47	47	26	24	4	351	23.18%	1.1	1.0
5	57	83	148	183	169	140	99	92	5	971	64.13%	1.0	
query:	WZ_TYPE=3			VEHNUM = 1,2,3,4,5,6,7,8,9					total	1514			
	CSEVERITY			FATALITIES				Frequency Ratio:		0.15			

Figure 5.8.2 – Spreadsheet Computation for Crash Severity and Frequency ratios

In order to create a crash severity ratio, the percentage of fatal crashes associated with a specific hazard was divided by the 0.90% that was obtained for all work zone fatal crashes. Figure 5.8.2, graphically displays this process for the hazard “build/rebuild under traffic – work on shoulder” where 0.79% of crashes in this category were fatal, 0.79/0.90 yields a severity ratio of 0.9 with rounding. This process was repeated for all severity levels (fatal, serious injury, minor injury, possible injury, and property damage only). It should be noted that the severity codes shown in Figure 5.8.2 are as defined by the crash code: 1=Fatal, 2=Major Injury, 3=Minor Injury, 4=possible injury, and 5=property damage only. The severity ranking of this section is not the same as the database values pertaining to crash severity. The purpose of the crash severity ratio is to ascertain the relative severity of a specific hazard. For instance, if the crash severity ratio is greater than one, the hazard can be assessed to be more severe than a typical crash (as described above). On the other hand, if the crash severity ratio is less than one (as shown in Figure 5.8.2) the hazard can be assessed to be less severe than a typical crash. Another noteworthy observation is the average severity ratio of minor injury, possible injury, and property damage only (severity level 3, 4, and 5, respectively) is generally "one." This indicates that generally the same proportion of minor injury, possible injury, and property damage only severity levels occur on all crashes regardless of the crash characteristics (or hazard). The crash severity ratios for the twenty two assessed hazards have been included in Appendix H.

5.4.3 Average Crash Severity Ratio:

In general, the number of vehicles involved in fatal crashes is relatively low; therefore, there can tend to be large variations in the results. Therefore, this research combines the effects of fatal crashes and serious injury crashes, both of which have serious implications to the persons involved and others, to determine severity rankings. The purpose of combining the two severity levels is to create a larger data set, in order to "smooth" out the variations posed by the analysis of small data sets. This was accomplished by averaging the crash severity ratio of fatal crashes with the crash severity ratio of major injury crashes. The far right column of Figure 5.8.2 displays the average severity ratio for this example. The average crash severity ratio of each hazard was then ranked on a scale from one to five based on its numerical distance from "one" based on the number of standard deviations.

The Average Severity ratio was created as a product of this research by expanding the severity ratio to include only crashes which resulted in fatal of serious injury. This is accomplished by summing the severity ratios for theses to severity levels and dividing by two to determine the average severity level:

Equation 5.8.3: Average Severity ratio:

$$SR_k^{avg} = \frac{1}{2}\sum_{i=1}^{2}\left\{\frac{\sum_{j=1}^{8} v_{ijk} \sum_{i=1}^{5}\sum_{j=1}^{8} w_{ij}}{\sum_{j=1}^{8} w_{ij} \sum_{i=1}^{5}\sum_{j=1}^{8} v_{ijk}}\right\}$$

Where; SR_k^{avg} = average severity ratio of fatal (i=1) and serious-injury (i=2) crashes for hazard/assessment k

5.4.4 Severity Ranking:

In order to utilize the results of the database analysis within the two dimensional risk matrix, it is necessary to rank each average severity ratio from one to five, where “one” is less severe and “five” is more severe than a “typical” crash. This ranking was accomplished by developing brackets in which the average severity ratio could be scored objectively. This requires the use of a statistical analysis of the distribution of average severity ratios for the fifty-six assessments that were performed in the previous section.

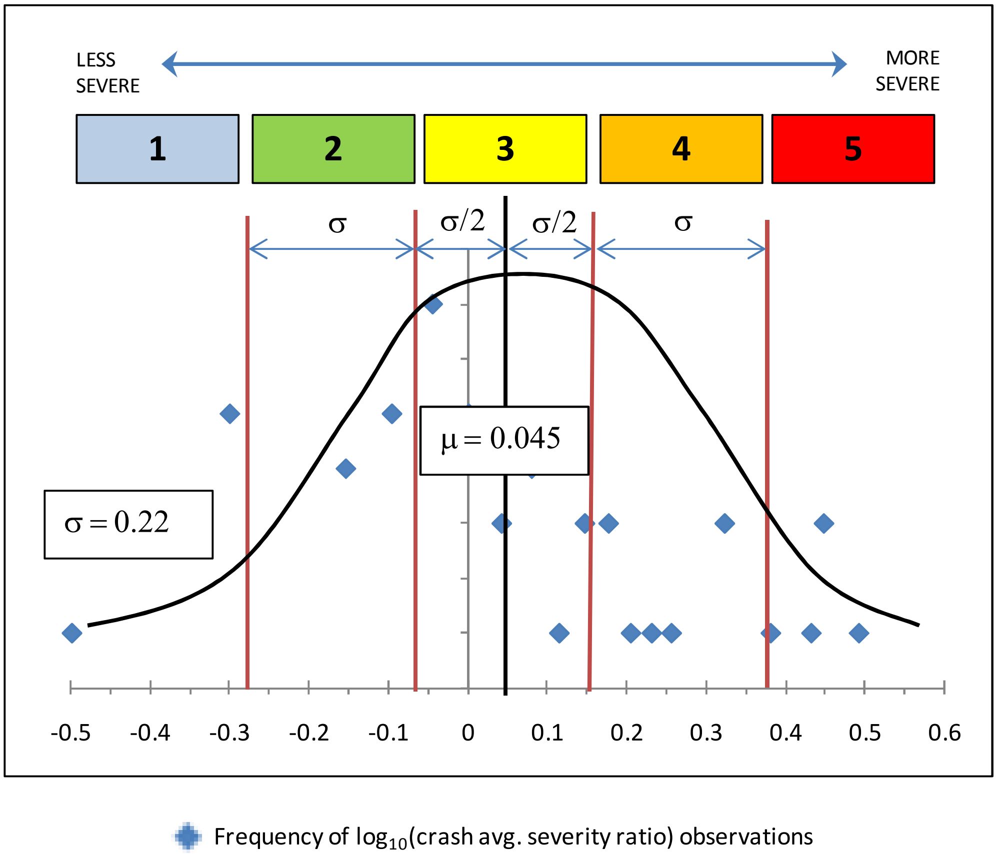


Figure 5.8.4 – Frequency Distribution ($\log_{10}$) – Crash Severity Ratio of Identified Hazards

In order to create the brackets for each of the five ranking levels, a statistical analysis of the observations that were queried through the database analysis was conducted. The mean and standard deviation was calculated from the sample of fifty-six assessments performed in the previous section. However, the raw data of the average severity ratios did not produce a normal distribution. Therefore, the data was converted into a normal distribution by a Log_{10} transformation. Figure 5.8.4 shows the normal distribution of the transformed data. The horizontal axis shows the Log_{10} of the average severity ratio for all assessments, and the vertical axis shows the number of observations or the frequency of occurrence for each severity ratio that was calculated. The transformed mean value of the average severity ratio was 0.045. Converted back; the mean average severity ratio is Log^{-1}_{10} (0.045) or 1.1. The transformed standard deviation is 0.22. Since a "typical" work zone crash has a severity ration of one, one will fall in the center position of the ranking scale. All other severity ratios would thereby fall above or below that number. A ratio greater than one is generally more severe than "typical" and a number less than one is generally less severe.

Table 5.8.4 – Severity Ranking Upper and Lower Limits

Severity Rank	Lower Limit	Upper Limit
1 - less severe	0	< 0.52
2 -	0.52	< 0.86
3 – severe	0.86	< 1.42
4 -	1.42	< 2.37
5 – more severe	2.37	None

The standard deviation and mean computed from the transformed data was utilized in order to form the upper and lower limits for each bracket of the ranking scale. The transformed brackets were then converted back to the original form using an inverse Log_{10} function. Figure 5.8.4 displays the normalized distribution with the brackets formed by using the transformed mean and standard deviation. The average severity ratio for rank number one has a lower limit of zero and an upper limit of less than Log^{-1}_{10} (-0.285) or 0.52. The average severity ratio limits for rank number 2 has a lower limit of 0.52 and an upper limit of less than Log^{-1}_{10} (-0.065) or 0.86. The average severity ratio for rank 3 has a lower limit of 0.86 and an upper limit of less than Log^{-1}_{10} (0.155) or 1.42. The average severity ratio for Rank 4 has a lower limit of 1.42 and an upper limit of less than Log^{-1}_{10} (0.375) or 2.37. Finally, the average severity ratio for Rank 5 has a lower limit of 2.37 and has no upper limit. Table 5.8.4 shows the upper and lower limits of each Average Severity Ratio ranking.

5.4.5 Frequency Ranking:

An equation used to compute the relative frequency for each hazard was developed as a product of this research by dividing the number of vehicles crashes for a particular hazard category by the total number of vehicles involved in work zone crashes over the eight year assessment period. The frequency ratio is expressed in the following relative frequency equation.

Equation 5.8.5: Relative Frequency equation:

$$RF_k = \frac{\sum_{i=1}^{5}\sum_{j=1}^{8} v_{ijk}}{\sum_{i=1}^{5}\sum_{j=1}^{8} w_{ij}}$$

Where: RF_k = relative frequency of hazard/assessment k

The relative frequency of each hazard was computed by dividing the total number of vehicle crashes with the characteristics of the identified hazard by the total number of vehicles involved in work zone crashes (10, 369). See the blue oval in Figure 5.8.2. The distribution of the relative crash frequencies was transformed in order to best represent a “normal” distribution. This was accomplished through a Log_{10} transformation of the data. Fifty-six observations of the crash data were included in this distribution.

In order to utilize the results of the database analysis within the two dimensional risk matrix, it is necessary to rank each relative frequency of crash from one to five, where “one” is less frequent and “five” is more frequent than a “typical” crash. This ranking was accomplished by developing brackets in which the relative frequency could be scored objectively. This required the use of a statistical analysis of the distribution of relative frequencies of the fifty-six assessments that were performed in the previous section.

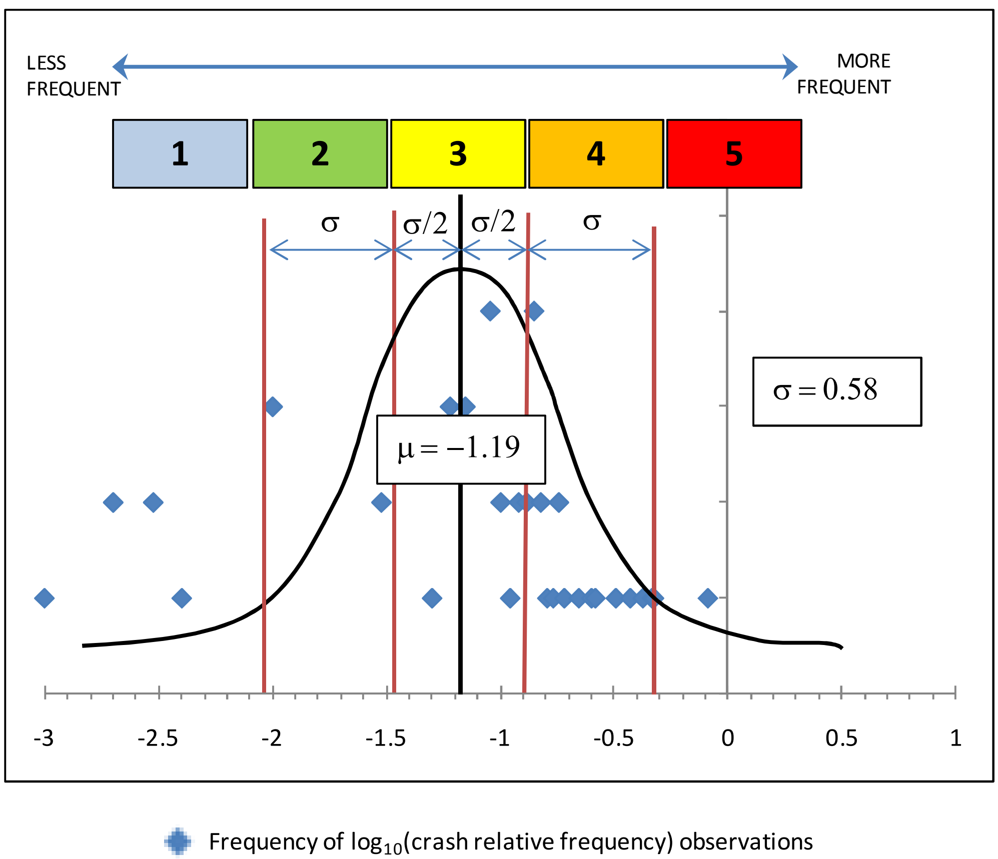


Figure 5.8.5 – Frequency Distribution ($\log_{10}$) –Relative Crash Frequency of Identified Hazards

In order to create the brackets in which each of the five ranks were to occupy, a statistical analysis of the observations collected through the database analysis was conducted. The mean and standard deviation was calculated from the relative frequencies of the fifty-six assessments performed in the previous section. However, as was the case with the severity ranking, the raw data of the relative frequencies did not produce a normal distribution. Therefore, the data was converted into a normal distribution by a Log_{10} transformation. Figure 5.8.5 shows the normal distribution of the transformed data. The horizontal axis plots the $\log_{10}$ of the average frequency ratio for all assessments, and on the vertical axis is the number of observations or frequency of occurrence for each of the relative crash frequencies that was calculated. The transformed mean value of the relative frequency was -1.19. Converted back; the mean relative frequency is Log^{-1}_{10} (-1.19) or 0.064. The transformed standard deviation is 0.58. For this research, the mean relative frequency was subjectively chosen to represent a "typical" work zone crash. Therefore the sample mean was chosen to occupy the center position of the ranking scale. All other relative frequencies would thereby fall above or below that number. A larger relative frequency with respect to the mean generally occurs more frequently than "typical" and a relative frequency less than the mean generally occurs less frequently.

Table 5.8.5 – Frequency Ranking Upper and Lower Limits

Frequency Rank	Lower Limit	Upper Limit
1 - less frequent	0	< 0.009
2 -	0.009	< 0.033
3 - frequent	0.033	< 0.125
4 -	0.125	< 0.480
5 – more frequent	0.480	1

The standard deviation and mean computed from the transformed data was utilized in order to form the upper and lower limits for each bracket of the ranking scale. The transformed brackets were then converted back to the original form using an inverse $\log_{10}$ function. Figure 5.8.5 displays the normalized distribution with the bracket formed by using the transformed mean and standard deviation. The relative frequency upper limit for rank number one has a lower limit of zero and an upper limit of Log^{-1}_{10} (-2.06) or 0.009. The relative frequency limits for rank number 2 has a lower limit of 0.009 and an upper limit of Log^{-1}_{10} (-1.48) or 0.033. The relative frequency limits for rank 3 has a lower limit of 0.033 and an upper limit of Log^{-1}_{10} (-0.9) or 0.125. The relative frequency limit for rank 4 has a lower limit of 0.125 and an upper limit of less than Log^{-1}_{10} (-0.32) or 0.48. Finally, the average severity ratio for Rank 5 has a lower limit of 0.48 and an upper limit of one. Table 5.8.5 shows the upper and lower limits of each relative frequency ranking.

5.4.6 Combined Risk Score:

A combined risk score was determined by combining the severity ranking and the frequency ranking on the two dimensional risk matrix shown in Figure 5.8.0. By multiplying the severity score by the frequency score, a risk score is computed. It is this portion of the research that relies on step one of the proposed integrated risk management program outlined in Chapter 4. Within the risk management policy statement is the requirement of the organization to indicate the goals, priorities and risk tolerance. Subjectivity is required in determining the threshold for risk tolerance that is acceptable for an organization. The risk scores range from one to 25 where "one" is a low risk score (low risk potential) and "25" is a high risk score which means that there is a relatively high risk potential.

Table 5.8.6a through Table 5.6.6c, displays risk potential of various work zone conditions. The hazards have been listed alphabetically; assessment numbers have been included in the first column. The average severity ratio and respective severity ranking is included in these tables. These tables also show the relative frequency and the frequency rank. Finally, the last column of these tables is the combined risk score.

Table 5.8.6a – Identified Hazards (Assessment #1 through #23) - Risk Score

Assess #	IDENTIFIED HAZARD	Average Severity Ratio	Severity rank	Frequency	Frequency rank	Risk Score
1	#3) build/rebuild under traffic - work on shoulder	0.8	2	0.15	4	8
2	#3) build/rebuild under traffic - intermittent or moving work	1.3	3	0.05	3	9
3	#4) construction vehicle traffic - dump trucks	2.1	4	0.02	2	8
4	#4) construction vehicle traffic – flatbed	2.8	5	0.01	2	10
5	#4) construction vehicle traffic - concrete mixer	0	1	0.002	1	1
6	#7) dirty/non-serviceable signs - traffic control device inoperative/missing/obscured	0.7	2	0.002	1	2
7	#8) driver/operator inattention	1.7	4	0.02	2	8
9	#9) driver/operator unfamiliarity (out-of-state driver license)	1.5	4	0.19	4	16
10	#9) inadequate/confusing traffic control (no controls present)	0.9	3	0.47	4	12
11	#11) falling debris/material (fallen object)	2.1	4	0.003	1	4
12	#13) inadequate buffer distance (crashes within or adjacent to work activity)	0.8	2	0.42	4	8
13	#16) inclement weather	1.2	3	0.09	3	9
14	#17) increased demand, inadequate capacity/geometry & confusing layout of: (lane closures)	0.9	3	0.46	4	12
15	#17) increased demand, inadequate capacity/geometry & confusing layout of: (lane shift/crossover)	1.6	4	0.12	3	12
16	#18) increased number of commercial trucks	2.1	4	0.1	3	12
17	#24) lack of visibility/glare/lighting (blinded by sun or headlights)	1.8	4	0.01	2	8
18	#24) lack of visibility/glare/lighting (dark-roadway lighted)	1.1	3	0.09	3	9
19	#24) lack of visibility/glare/lighting (dark-roadway not lighted)	2.8	5	0.06	3	15
20	#28) poor driver skills (operator error)	1	3	0.25	4	12
21	#28) poor driver skills (aggressive driving)	2.4	5	0.02	2	10
22	#29) poor visibility of workers (#veh involved in crash w/ worker)	14.7	5	0.004	1	5
23	#31) railroads	3.1	5	0.003	1	5

Table 5.8.6b – Identified Hazards (Assessment #24 through #37) - Risk Score

Assess #	IDENTIFIED HAZARD	Average Severity Ratio	Severity rank	Frequency	Frequency rank	Risk Score
24	#32) road characteristics through the work zone (intersections)	0.8	2	0.22	4	8
25	#32) road characteristics through the work zone (ramps)	1.2	3	0.11	3	9
26	#32) road characteristics through the work zone (blind spot/obscurement)	0.3	1	0.03	2	2
27	#32) road characteristics through the work zone (bridge/overpass/underpass)	0.9	3	0.09	3	9
28	#32) road characteristics through the work zone (shoulders - none/low/soft/high)	0	1	0.001	1	1
29	#33) the condition of roadway (road surface condition/debris /ruts/holes/bumps/worn surface)	1.1	3	0.02	2	6
30	#34) the points of merge (between advance warning & work area; within transition area for lane shift)	1	3	0.32	4	12
31	#35) the posted speed through the work zone (65 mph)	2.7	5	0.06	3	15
32	#35) the posted speed through the work zone (55-60 mph)	1.4	3	0.37	4	12
33	#35) the posted speed through the work zone (40-50 mph)	0.5	1	0.14	4	4
34	#35) the posted speed through the work zone (30-35 mph)	0.5	1	0.26	4	4
35	#35) the posted speed through the work zone (< 25 mph)	0.5	1	0.14	4	4
36	#38) traffic congestion & delay through the work zone (evasive action)	1.1	3	0.07	3	9
37	#39) traffic speed & speeding (exceeded authorized speed)	2.8	5	0.01	2	10

Table 5.8.6c – Identified Hazards (Assessment #38 through #56) - Risk Score

Assess #	IDENTIFIED HAZARD	Average Severity Ratio	Severity ranking	Frequency	Frequency ranking	Risk Score
38	#12) high risk traffic – Sundays	1.4	3	0.06	3	9
39	#12) high risk traffic – Mondays	0.5	1	0.15	4	4
40	#12) high risk traffic – Tuesdays	0.8	2	0.16	4	8
41	#12) high risk traffic – Wednesdays	0.9	3	0.17	4	12
42	#12) high risk traffic – Thursdays	1	3	0.18	4	12
43	#12) high risk traffic – Fridays	1.2	3	0.18	4	12
44	#12) high risk traffic – Saturdays	1.4	3	0.09	3	9
45	#10) seasonal road use – January	0.9	3	0.02	2	6
46	#10) seasonal road use – February	0.7	2	0.02	2	4
47	#10) seasonal road use – March	0.5	1	0.03	2	2
48	#10) seasonal road use – April	1	3	0.07	3	9
49	#10) seasonal road use – May	0.8	2	0.1	3	6
50	#10) seasonal road use – June	1.5	4	0.13	4	16
51	#10) seasonal road use – July	0.9	3	0.13	4	12
52	#10) seasonal road use – August	0.7	2	0.14	4	8
53	#10) seasonal road use – September	1.5	4	0.14	4	16
54	#10) seasonal road use – October	0.7	2	0.12	3	6
55	#10) seasonal road use – November	1.2	3	0.07	3	9
56	#10) seasonal road use – December	1	3	0.02	2	6

5.4.7 Assessment Matrix Conclusions:

The results displayed in Tables 5.8.6a through 5.8.6c, should be used in conjunction with the two dimensional matrix of Figure 5.8.0 above. For the frequency and severity rankings, any risk that was assessed as a five was color coded red, in order to send a "red flag" for the risk management team. Also, since the "typical" crash is assigned a three in both severity and frequency, it is determined that a combined risk score of nine is considered a moderate risk. This means that risk score greater than nine is considered a higher risk and anything lower than nine is a lower risk. The risk matrix displays a band through the middle and assigns a moderate risk category to risk scores of between eight and ten. Therefore, for this research, any risk score greater than ten has been highlighted in order to bring attention to the associated hazard. In the risk score column of Table 5.8.6a through Table 5.8.6c, the cell containing the risk score has been filled if the score was greater than ten.

Six hazards have been assessed with a severity score of five, and none of the hazards scored a five in frequency:

- dark conditions/roadway not lighted;
- poor driver skills (aggressive driving);
- poor visibility of workers;
- railroads;
- the posted speed through the work zone (65 mph); and
- traffic speed and speeding (exceeded authorized speed).

However, sixteen hazards were identified to have a combined risk score greater than ten:

- driver/operator unfamiliarity;
- inadequate/confusing traffic control (no controls present);
- lane closures;
- lane shift/crossover (head to head);
- commercial trucks;
- dark conditions – roadway not lighted;
- poor driver skills (operator error);
- the points of merge;
- the posted speed through the work zone (65 mph zone, & 50-60 mph zone);
- high risk traffic (Wednesdays, Thursdays, & Fridays); and
- seasonal road use (June, July, & September)

According to the logic and methodology of this research, these hazards should be determined to have priority when mitigating work zone hazards.

The next section will examine the response of potential risks. Risk response has been accomplished through the development of risk mitigation identification tools and methodology, and through a composite list of mitigation strategies that have been identified for each phase of the project development process from the results of the focus group discussion and the on-line survey.

5.5 RISK RESPONSE (TREATMENT)

The final step in the standard risk management model is the risk response or treatment. As mentioned in the previous chapters there are several different risk responses which can be undertaken: risk avoidance (elimination), risk reduction (mitigation), risk retention (accepting and budgeting), and risk transfer (insurance and hedging). The focus of this research is loss prevention from the position of preventing losses associated with work zone crashes and fatalities. Ultimately, this research is interested in the mitigation of risks associated with vehicle crashes in work zones. However, during each project phase, a separate risk response may be applied to a particular risk. For example, during the planning phase a possible course of action for a particular need may pose a specific risk to the stakeholders—at this point that risk can be eliminated or it can be retained in that phase with the intent of treating the risk in a subsequent phase. The combination of responses to the risk in each of the project phases ultimately leads to a reduction in either the frequency or the severity of the risk. This section will identify the various risk treatments or mitigation strategies that can be utilized during each of stage of the project development process. The methodology for this section is identical to that of the risk identification phase.

5.5.1 Risk Response Methodology

The methodology for this section starts with the content analysis of journal articles, Department of Transportation (DOT) memorandums, and research papers in order to develop the initial list of mitigation strategies; this list was then organized and grouped into various compartments for qualitative assessment of mitigation source and mitigation method. These assessments were utilized to establish the general category in which the project stakeholder and project activity were best suited to manage the risk. The categorization of these mitigation strategies also allowed the researchers to develop the method that would assist the risk management team during the brainstorming sessions intended to identify mitigation strategies for a particular project and the respective project phase.

Once the initial list and brainstorming cues were developed, a partial list of mitigation strategies was compiled and aligned with the project phases in which it was most likely to be associated. This was developed in order to assist the focus group by providing a starting point and a prompt list to stimulate the thought processes. The product of the focus group was a comprehensive list of mitigation strategies that applied to the specific hazards identified in the previous section of this research. The results of the focus group were arranged into the form of a questionnaire that was prepared by Zoomerang®, an on-line survey provider. The purpose of the survey was to validate the findings of the expert panel and to identify any additional mitigation strategies that were not identified during the focus group discussion.

5.5.2 Countermeasures for the Various Factors Contributing to Crashes in Work Zones (Key Components to Accident Mitigation):

The qualitative assessment of the results from content analysis of papers and journals resulted in the development of the categorization of accident (crash) mitigation strategies in terms of key components. Although many factors have been addressed in terms of accident prevention, specifically addressing accident mitigation in terms of components is critical. This will aid in developing an integrated risk management model that spans the entire project development process. Addressing accident prevention in terms of components has not been emphasized in much past research. That said, the literature review revealed general measures that can be used to prevent accidents and injuries in work zones. These measures have typically been compiled into extensive lists of recommended best practices or future innovation. It is the desire of this research to develop a methodology for accident mitigation by defining the key components of accident mitigation. This will help to initially correlate the mitigation strategy with the corresponding project phase or phases.

It can be shown that by identifying the key components of work zone accident mitigation a procedure or process can be developed in order to determine which party or parties is best suited to manage the mitigation strategies of each component. As a result of a qualitative assessment of the list of mitigation strategies compiled by various sources, five components have emerged:

- Education
- Enforcement

- Design/Planning
- Scheduling
- Construction Operations.

Table 5.9.2 provides a brief outline showing some of the sub-items of each of the identified components. These components include education, enforcement/legislation, design/planning, scheduling/contraction and construction operations. Educations concerns action items such as information, training, and signage to inform the public of work zone issues. Enforcement/legislation includes measures which can be enforced on site or the creation of new policy to address such issues, whether at the state level or at the project level. The design or planning stages must ensure that design criteria meets project requirements (such as Highways for Life requirements). The construction scheduling must take in account local and regional events and requirements. In addition, innovative contracting can focus on safety requirements. At the time of construction, many of the mitigating strategies are practically applied.

Table 5.9.2 – Mitigations Strategies by Component

COMPONENT	MITIGATION STRATEGIES
Education	▪ Information • General project information • Lane closures locations and dated • Alternate routes • Media Outlets • Work Zone Awareness Initiatives • Coordinate with local police/public ▪ Training • Driver training (signs, seatbelts, etc.) • Worker Safety Training • Flagger Training ▪ Signage • Information Boards • Late lane Merges • Chevrons
Enforcement/Legislation	▪ Speed Control ▪ Traffic Control ▪ Vandalism Prevention (Stealing signs, etc.) ▪ Surveillance ▪ Driver Assistance (break downs, etc.) ▪ Fines (fines double in work zones) /litigation ▪ Accident Investigation/ crash record keeping
Design/Planning	▪ MUTCD ▪ Highways for life Programs (planning & programming) ▪ Business Owners requirements (planning & programming) ▪ Traffic Control Plans ▪ ID Project Particulars & critical events ▪ Coordinate between stakeholders
Scheduling/Contracting	▪ Job site congestion/activities ▪ Civic and Cultural Events/Programs ▪ Construction schedule ▪ Bid Items for safety ▪ Bid Items for Driver Assistance ▪ Bid Items for Monitoring/Surveillance ▪ Bit Items for construction vehicle spotters and ground guides
Construction Operations	▪ Flagging ▪ Barricading ▪ Re-routing traffic ▪ Internal Traffic Control Plans (Contractor) ▪ Monitoring/Surveillance on off hours ▪ Construction Traffic/congestion • Heavy equipment • Commercial Trucks and Equipment ▪ Driver Assistant programs ▪ Accident Investigation ▪ Procedures for reporting/documenting "near misses"

5.5.3 Mitigation Methods

The countermeasures for the various factors are determined through the risk mitigation strategies. The hazards are mitigated by different measures. Through the development of this research, it was determined that the most effective way to apply a mitigation strategy was through the implementation of several methods that are intended to serve as a means to interact with the motorists. This research has identified the following methods of interaction: alert motorist, assist worker/motorist, control motorist, inform motorist, protect worker/motorist. These methods are used by various entities throughout the project life cycle. In order to determine the source of the mitigation strategy, it is necessary to identify the components of crash mitigation.

Mitigation Methods:

- Alert Motorist
- Assist Motorist / Worker
- Control Motorist
- Inform Motorist
- Protect Worker/Motorist

Figure 5.9.3 – Mitigation Methods

As indicated by Table 5.9.3 below, the list of hazards and mitigation strategies is extensive. The intent of this portion of the research is to develop a checklist for the risk management team along with establishing scenario based questions that will accompany brainstorming sessions to identify hazards and mitigation strategies. These scenario based questions are based on the established primary cause (loss of control, loss of visibility, and confusion) to identify potential hazards on the plans, designs, or jobsite. The scenario based questions that cue the risk response that addresses mitigation strategies may take the form of the mitigation method (alert motorist, assist worker/motorist, control motorist, inform motorist, and protect worker/motorist).

Assembling a list of mitigation strategies from various sources allows for the development of categories that delineate mitigation sources. These sources allow the risk management team to identify the project phase in which the mitigation strategies may be applied. This is the first step in formalizing the risk management process. Tables 5.9.3a through Table 5.9.3e list the mitigation strategies in terms or the five components of risk mitigation for work zones. Table 5.9.3a displays mitigation strategies that have been categorized by Education. Table 5.9.3b displays mitigation strategies that have been categorized by Enforcement/Legislation. Table 5.9.3c displays mitigation strategies that have been categorized by Design/Planning. Table 5.9.3d displays mitigation strategies that have been categorized by Scheduling/Contracting. And Table 5.9.3e displays mitigation strategies that have been categorized by Construction Operations. As shown in these tables, the same mitigation strategies may be applied through several entities or mitigating sources.

Table 5.9.3a – Mitigations Strategies Applicable to Education

EDUCATION (INFORMATION, SIGNAGE, TRAINING)		
MITIGATION STRATEGY	**METHOD**	**SOURCE**
coordinate with local police	control motorist	Hausman 2007
advance warning to motorist	inform motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
educate public about work zones	inform motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
inform media of upcoming roadwork	inform motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
provide alternate routes	inform motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
public relations (project info, dates, alt routes)	inform motorist	Hausman 2007
real time information radio broadcast	inform motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
flashing lights	alert motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
signals - stop/go	alert motorist	Texas Tech (Hill et al. - 2003)
Changeable Message Signs (CMS)	control motorist	Garber and Patel - 1994 (VRTC & VDOT)
Changeable Message Signs (CMS)	control motorist	Richard and Dudek – 1986
temporary traffic control, signage, warning device	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
Variable Speed Limit	control motorist	Yadlapati and Park - 2004
need more effective signage	inform motorist	Benekohal et al. 1995 (IDOT)
need more work zone signs	inform motorist	Benekohal et al. 1995 (IDOT)
portable changeable message signs	inform motorist	Bushman ad Bethelot - 2005 (NCDOT)
post warning signs 3-5 miles ahead	inform motorist	Benekohal et al. 1995 (IDOT)
real time information signage	inform motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
employee training	protect worker/motorist	Hall and Lorenze - 1989 (NMSTHD & FHWA)
employee training	protect worker/motorist	Hausman 2007

Table 5.9.3b – Mitigations Strategies Applicable to Enforcement/Legislation

ENFORCEMENT/LEGISLATION		
MITIGATION STRATEGY	**METHOD**	**SOURCE**
provide alternate transportation modes	assist worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
increase fines - speed, alcohol, drugs	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
law enforcement	control motorist	Richard and Dudek – 1986
Police Presence	control motorist	Huebschman et al. - 2003 (Purdue University)
police presence	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
Police Presence & Police Cars with Flashing Lights	control motorist	Arnold - 2003 (VTRC & FHWA)
regulatory speed zoning	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
speed controls	control motorist	VDOT (Garber and Zhao - 2002)
speed controls (55 mph too high)	control motorist	Benekohal et al. 1995 (IDOT)
speed limit	control motorist	Richard and Dudek – 1986
Variable Speed Limit	control motorist	Yadlapati and Park - 2004
crash record keeping	protect worker/motorist	Hall and Lorenze - 1989 (NMSTHD & FHWA)

Table 5.9.3c – Mitigations Strategies Applicable to Design/Planning

DESIGN/PLANNING		
MITIGATION STRATEGY	**METHOD**	**SOURCE**
Conspicuity Modeling	alert motorist	Barton et al. - 2001 (California Path Program)
increase size of traffic control devices	alert motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
Rumble Strips - transition area	alert motorist	Mitchell et al. – 2005
install lighting	assist worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
provide consistency in work zone	assist worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
channelizing with cones and barrels	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
effective lane width reduction	control motorist	Richard and Dudek – 1986
lane reduction	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
late merge traffic control	control motorist	Beacher – 2005
MUTCD (w/ multiple traffic control devices used in an array)	control motorist	Pain et al. - 1983 (National Cooperative Highway Research Program)
Narrow Lane through work zone	control motorist	Mitchell et al. – 2005
Optical Speed Bars	control motorist	Meyer - 2004 (KTRAN)
TCP's (preparation & modification)	control motorist	Hall and Lorenze - 1989 (NMSTHD & FHWA)
temporary traffic barriers	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
Traffic Control practices and procedures	control motorist	Hargroves - 1981 (FHWA & VDOT)
Changeable Message Signs (CMS)	inform motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
placement of information boards	inform motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
buffer distance (traffic and activity)	protect worker/motorist	VDOT (Garber and Zhao - 2002)
curve realignment (non-work zone)	protect worker/motorist	Yuan et al. - 2001 (University of Connecticut)
increase taper length - night const	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
length of work zone (keep under 0.6 mile)	protect worker/motorist	Garber and Woo - 1990 (University of Virginia)
maximize lateral buffer zone	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
minimize length of work zone	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
road closure / reroute traffic	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
truck mounted attenuators	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)

Table 5.9.3d – Mitigations Strategies Applicable to Scheduling/Contracting

SCHEDULING/CONTRACTING		
MITIGATION STRATEGY	**METHOD**	**SOURCE**
change color of barriers	alert motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
install reflectors, lights	alert motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
install low level transitional lighting	assist worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
specify temporary pavement markings	assist worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
pace vehicle to slow traffic	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
provide flaggers	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
bid items for safe workzone set up	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
clean/maintain channelizing devices	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
contractor hazard assessments	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
develop internal traffic control plans	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
preconstruction meetings - hazards	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
work zone duration	protect worker/motorist	VDOT (Garber and Zhao - 2002)

Table 5.9.3e – Mitigations Strategies Applicable to Construction Operations

CONSTRUCTION OPERATIONS		
MITIGATION STRATEGY	**METHOD**	**SOURCE**
change color of barriers	alert motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
flashing arrows	alert motorist	Garber and Woo - 1990 (University of Virginia)
flashing lights	alert motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
install reflectors, lights	alert motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
mark construction equipment - reflective tape	alert motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
install lighting	assist worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
install low level transitional lighting	assist worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
barricades reduce effectiveness of traffic control when used in combination	control motorist	Garber and Woo - 1990 (University of Virginia)
channelizing with cones and barrels	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
Cones	control motorist	Garber and Woo - 1990 (University of Virginia)
effective lane width reduction	control motorist	Richard and Dudek – 1986
Flagger	control motorist	Richard and Dudek – 1986
flagger/officer	control motorist	Texas Tech (Hill et al. - 2003)
Flaggers	control motorist	Garber and Woo - 1990 (University of Virginia)
install temporary traffic control in timely manner	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
lane reduction	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
late merge traffic control	control motorist	Beacher – 2005
MUTCD (w/ multiple traffic control devices used in an array)	control motorist	Pain et al. - 1983 (National Cooperative Highway Research Program)
pace vehicle to slow traffic	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
provide flaggers	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
state trooper patrol work area	control motorist	Hausman 2007
timely removal of channelizing devices	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
timely removal of signage	control motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
Traffic Control practices and procedures	control motorist	Hargroves - 1981 (FHWA & VDOT)
advance warning to motorist	inform motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
Changeable Message Signs (CMS)	inform motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
placement of information boards	inform motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
portable changeable message signs	inform motorist	Bushman ad Bethelot - 2005 (NCDOT)
real time information radio broadcast	inform motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
real time information signage	inform motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
clean/maintain channelizing devices	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
contractor hazard assessments	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
daily safety meetings	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
develop internal traffic control plans	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
employee health screening	protect worker/motorist	Hausman 2007
increase taper length - night const	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
maintain traffic control devices	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
maximize lateral buffer zone	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
minimize length of work zone	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
preconstruction meetings - hazards	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
road closure / reroute traffic	protect worker/motorist	Pratt et al. - 2001 (Dept of Health and Human Services)
safe work practices	protect worker/motorist	Hausman 2007
safety equipment	protect worker/motorist	Hausman 2007
safety inspections	protect worker/motorist	Hall and Lorenze - 1989 (NMSTHD & FHWA)
Servicing of construction equipment	protect worker/motorist	Hausman 2007
work crew to assist motorist breakdown	protect worker/motorist	Hausman 2007

During the content analysis, the mitigation strategies were not necessarily presented in terms of a risk response. They were typically provided in the literature as a means of addressing work zone safety. However, the creation of a list of mitigation strategies allowed for the development of a comprehensive risk management model. The result of this research is a formal process that links mitigation strategies to specific identified hazards and to specific mitigation sources as determined by each of the five components of work zone crash mitigation. This general idea was utilized while reviewing the results of the focus group discussion.

5.5.4 Focus Group – Risk Treatment/Response

During the focus group discussion, the primary investigator (PI) led the expert panel through each of the project development phases. During each phase, the panel was asked to identify mitigation strategies that could be applied during that particular phase. The questions were not necessarily designed as a direct response to the identified hazard but were designed in such a way as to solicit discussion pertaining to the state of the practice, best practices, and recommended future practices that could be applied to work zone safety for each phase of the project. Information was solicited from focus group participants as applicable to each particular project phase. Identified hazards were then linked to the mitigation strategies based on feedback from the expert panel. The results of the expert panel were then formed into a questionnaire for an on-line survey that was sent out to industry professionals with experience in planning & programming, design, letting & award, and construction. Appendix C provides the results of the focus group discussion. No additional analysis was conducted on the results of the expert panel, the main objective was to merely identify the mitigation strategies that applied to each project phase.

5.5.5 Survey Results – Risk Treatment/Response:

Participants in the on-line survey were asked to identify possible mitigation strategies for each of the 39 hazards that were identified during the risk identification process. They were instructed to only check the mitigation strategies that they agreed with. The survey participants were also instructed to write in additional mitigation strategies for each hazard. Professionals from government agencies, construction companies, and consulting agencies were invited to participate in the survey. Unfortunately, there was a relatively low response rate for the survey. However, the qualitative data that was gained from the survey was very beneficial. No statistical analysis was performed; however, a comprehensive list of mitigation strategies was compiled. This will serve future risk mangers in roadway work zones in selecting mitigating strategies from an existing list of strategies and will provide a basis for the stimulation of innovation.

Tables 5.11.1a thru 5.11.1k show the 39 hazards that were identified in the first step of this process. For each of the hazards, a list of mitigation strategies was provided for each phase where the expert panel identified the hazard. The tables include additional write-in responses from some the participants of the on-line survey. (These write-in mitigation strategies are written in italics.)

Table 5.11.1a – Mitigations Strategies by Project Phase (hazard #1 thru #5)

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		Mitigation Strategies by Project Phase			
	IDENTIFIED HAZARD	**PLANNING & PROGRAMMING**	**DESIGN**	**LETTING & AWARD**	**CONSTRUCTION**
1	**a contract that does not include a final schedule showing project duration and event planning**			• Require that the schedule and sequencing are conditions of the contract including: meetings, specific requirements	

2	**accelerated project completion requirements (i.e., overexposure of workers; inclement weather construction; external construction completion date requirement -harvest, overlay cure time, etc.)**	• Select materials that may minimize construction duration
		  ◦ PCC/ACC, etc.
		  ◦ Full Depth vs. Overlay
		• Use innovative contracting methods (A+B, I/D Clauses, lane rental specifications)
		• Early letting to allow for early procurement to meet long lead times
		• Accept risk and manage/control during subsequent phases
		  ◦ Design phase
		  ◦ Construction phase
			• Awareness initiatives, speed control, driver training
			• Reflectorized barriers, rails, etc.
			• High visibility worker apparel
			• Develop innovative contracting methods (A+B, I/D Clauses, lane rental specifications)
			• Specify early letting to allow for early procurement to meet long lead times
			• Conduct constructability reviews
			• Accept risk and manage/control during subsequent phases
			  ◦ Construction phase
					• Awareness initiatives, speed control, driver training
					• Reflectorized barriers, rails, etc.
					• High visibility worker apparel
					• Rumble strips

3	**build/rebuild under traffic**	• Detours
		• Road Closures
		• Lane Closures
		• Accept risk and manage/control during subsequent phases
		  ◦ Design phase (construction phasing for demo work,etc.)
		  ◦ Construction phase
			• Determine construction phasing for demo work,etc.
			• Conduct constructability reviews
			• Accept risk and manage/control during construction phase
					• Traffic awareness
					• Monitor traffic safety issues
					• Truck mounted attenuators
					• High visibility worker apparel
					• *Temp. stop work during some periods of heavy traffic*
					• *Public out-reach*
					• *ITS signs*

4	**construction vehicle traffic**		• Develop schematic Internal Traffic Control Plans (use early contractor involvement) • Specify Ingress/egress points • Accept risk and manage/control during construction phase		• Implement and adjust Internal Traffic Control Plans • Employ & enforce points of ingress/egress • *Construction sequencing meetings* • *Back-up alarms*

Table 5.11.1b – Mitigations Strategies by Project Phase (hazard #5 thru #8)

		Mitigation Strategies by Project Phase			
	IDENTIFIED HAZARD	**PLANNING & PROGRAMMING**	**DESIGN**	**LETTING & AWARD**	**CONSTRUCTION**

5	**contractor complacency**			• Outline contractor fines and sanctions as contract requirements
				  • For lack of project management
				  • For lack of proper traffic control
				• Use of contractor evaluations for bid capacity	

6	**contractor selection process**			• Prequalify contractor based on worker safety training program • Use of contractor evaluations for bid capacity • Prequalify contractor using safety record • Insurance rate factors	
7	**dirty/non-serviceable signs/reflectors, etc.**				• Clean and maintain signs, reflectors, etc • Ensure that sign maintenance is part of safety compliance program • *Dis-incentive for non-compliance with maintenance*
8	**driver / operator inattention**		• Design/specify rumble strips • Taper Designs follow up-to-date MUTCD (reflective) • Specify high visibility worker apparel • Specify CB Radio message in vicinity of transition area • Specify use of ITS (intelligent transportation systems) • Accept risk and manage/control during construction phase		• Taper designs to follow up-to-date MUTCD (reflective) • Utilize/employ ITS systems • Ensure high visibility worker apparel • install portable rumble strips • Announcement on CB radios in transition areas • *Presence of law enforcement*

Table 5.11.1c – Mitigations Strategies by Project Phase (hazard #9 and #10)

		Mitigation Strategies by Project Phase			
	IDENTIFIED HAZARD	**PLANNING & PROGRAMMING**	**DESIGN**	**LETTING & AWARD**	**CONSTRUCTION**

9	**driver confusion from: too many decisions (especially at higher speeds); driver/operator unfamiliarity; and inadequate/confusing traffic control**		• Design for Positive Traffic Control - Signage (get signs made up ahead of time)
			  • detour
			  • temporary barrier rails (channelizing)
			  • minimize posted signage (less is more)
			  • use CMS (changeable message signs), but minimally before entering area
			  • flashing arrows
			• Education/Information for unfamiliar drivers
			• Media (radio/TV), website, advanced warning signs)
			• Visualization in 3D (information prior to driving in work zones) used in Council Bluffs
			• Accept risk and manage/control during subsequent phases
					• Employ ITS - early warning (multiple simultaneous methods) place in sufficient distance ahead of decision area
					• CMS (changebale message signs)
					• Flashing arrow
					• Properly Constructed Taper (updated MUTCD)
					• Increase use of reflectorized arrow, signs, painting, etc.
					• Information OUTLETS
					  • Resident Engineer office
					  • 511 (cell phones)
					  • IA.org (internet)
					• Media outlet for project information
					  • Lane Closures
					  • Traffic information
					  • Alternate routes
					  • Detours

10	**extra traffic volume through the workzone from: construction traffic; civic events; holidays; and seasonal traffic/road use**	• Accept risk and manage/control during subsequent phases
		  • Design phase (alignment, geometry, etc.)
		  • Final Design (schedule, standard specs, etc.)
		  • Letting & Award phase (construction schedule)
		  • Construction phase (Construction Scheduling)
			• Design phase (alignment, geometry, etc.)
			• Final Design (schedule, standard specs, etc.)
			• Planning Calendar as part of Bid Documents
			  • Special events
			  • Harvest season completions
			• Schedule Visualization in 3D
			• Accept risk and manage/control during subsequent phases
			  • Letting & Award phase (construction schedule)
			  • Construction phase (Construction Scheduling)
				• Pre-bid meeting to discuss construction schedule
				• Spell out limitations to contract
				  • Minimize construction operations
				  • No major activities
				  • Minimize excess traffic
				• Manage During Construction Phase (scheduling)
					• Coordination meetings
					• Construction scheduling
					• Restricted construction activities based on planning calendar (updated by district)
					  • Special events
					  • Harvest season completions
					• Visualization in 3D of schedule provided

Table 5.11.1d – Mitigations Strategies by Project Phase (hazard #11 thru #15)

		Mitigation Strategies by Project Phase			
	IDENTIFIED HAZARD	**PLANNING & PROGRAMMING**	**DESIGN**	**LETTING & AWARD**	**CONSTRUCTION**

11	**falling debris/material from: overhead structures & blasting**	• Detours
		• Road Closures
		• Lane Closures
		• Accept risk and manage/control during subsequent phases
		  • Design phase (construction phasing for demo work,etc.)
		  • Construction phase
			• Construction Phasing
			• Construction Schedule
			• Traffic Control Plans
			• Accept risk and manage/control during subsequent phases
			Construction phase (contractor mitigation)
					• Require constractor submittal of protection plan
					• Implement construction phasing
					• Uphold construction schedule
					Monitor traffic control effectiveness

12	**high risk traffic (i.e., Fridays, evenings – (bar time), and rush hour traffic)**		• Develop limits to contract (workday restrictions, etc) • Accept risk and manage/control during subsequent phases	• Review limits to contract (workday restrictions, etc) Accept risk and manage/control during subsequent phases	• Uphold limitations to contract • Event Calendar Updates from District • Coordination meetings Law Enforcement
13	**inadequate buffer distance from travel lane to work area**		• Design adequate buffer space • Provide positive protection (barriers) • Accept risk and manage/control during construction phase		• Ensure/maintain adequate buffer space • Worker safety training • Reduce traffic speed (positive control & law enforcement) • Barriers • *Communicate inadequacies with possible corrections* • *Crash attenuators*
14	**inadequate contractor accountability for safety**			• Establish contractor management structure addressing safety as a qualification requirement • Use of contractor evaluations for bid capacity Prescribe minimum site visits by safety director	

Table 5.11.1e – Mitigations Strategies by Project Phase (hazard #16 thru #18)

		Mitigation Strategies by Project Phase			
	IDENTIFIED HAZARD	**PLANNING & PROGRAMMING**	**DESIGN**	**LETTING & AWARD**	**CONSTRUCTION**
15	**inadequate internal traffic control plans (ITCPs)**				• Develop ITCP specifically for the anticipated traffic and operating procedures • *Discuss problems & solutions with contract authority* • *Communicate inadequacies with possible corrections*
16	**inclement weather**		• Awareness initiatives • Speed control • Reflectorized barriers, rails, etc • High visibility worker apparel • *Consider signage & CBM warnings*		• Driver awareness initiatives • Speed control • Driver training • Reflectorized barriers, rails, etc • High visibility worker apparel

17	**increased demand of, inadequate capacity/geometry & confusing layout of: detours; road closures; and lane closures (moving & stationary)**		• Upgrade conditions/geometry
			• *Change or modify detour route layout & devices*
			• Traffic control plans (signs, barriers, etc)
			• Accept risk and manage/control during subsequent phases (media outlets/education/information/closure dates)
					• Field upgrade conditions/geometry
					• Employ traffic control plans (signs, barriers, etc)
					• Utilize Media outlets
					  • Education
					  • Information (closure dates, etc)
					• Monitor and recommend improvements

18	**increased number of commercial trucks on existing routes or alternate routes**	• *hazard was identified but no strategies were listed*	• *detour signage* • *review traffic control on possible parallel routes w/ local jurisdictions* • *consider traffic control plans for those routes* • *Specify commercial vehicle routes* • *Modify traffic control on designated routes* • *Acknowledge the existence of commercial trucks using signage*		• Awareness initiatives, speed control, driver training • Reflectorized barriers, rails, etc. • High visibility worker apparel • Rumble strips • *Outreach to trucking associations*

Table 5.11.1f – Mitigations Strategies by Project Phase (hazard #19 thru #22)

		Mitigation Strategies by Project Phase			
	IDENTIFIED HAZARD	**PLANNING & PROGRAMMING**	**DESIGN**	**LETTING & AWARD**	**CONSTRUCTION**
19	**jobsite congestion & traffic resulting in local traffic congestion and delays**		• Ensure constructability reviews and sequencing for concept of work (reverse schedule construction) • Provide schedule and allowance incentives & workday constraints • Accept risk and manage/control during construction phase		• Implement sequencing for the concept of work • Satisfy schedule and allowance incentives & workday constraints • Communicate traffic restrictions on DOT website (particularly for oversized loads through workzones) • Ground guides (on-site) to prevent motorists from entering worksite • Use of ground guides to manage on-site construction traffic (particularly large trucks) • *Reduce jobsite congestion to reduce traffic congestion!*
20	**lack of accident/near-miss reporting structure**			• Bid item for on-site safety technician • Bid item for on-site surveillance	

21	**lack of contractor innovation in traffic control methods**		• Bid Items for traffic control adjustments
			• Assign bid items for traffic control
			• Assign responsibility – bid items
			• Accept risk and manage/control during subsequent phases
			  • Letting
			  • construction
				• Bid items for traffic control adjustments
				• Assign bid items for traffic control
				• Assign project responsibility
				• Manage During Construction Phase
					• Bid items for traffic control adjustment
					• Encourage value engineering proposals
					• Assign bid items for traffic control
					• Assign responsibility for bid items
					• *Strong inspection and accountability for action*

Table 5.11.1g – Mitigations Strategies by Project Phase (hazard #23 thru #26)

		Mitigation Strategies by Project Phase			
	IDENTIFIED HAZARD	**PLANNING & PROGRAMMING**	**DESIGN**	**LETTING & AWARD**	**CONSTRUCTION**
22	**lack of contractor project management (directed toward safety)**			• Prequalify contractors based on expertise of project management team • Use of contractor evaluations for bid capacity	
23	**lack of positive control of traffic**		• Develop contracting language & constraints (training, flaggers, barricades, signs/signals, traffic control, etc.) • Provide bid items for use of barriers • Specify use of ITS (intelligent transportation systems) • Accept risk and manage/control during construction phase		• Training • Flaggers • Barricades • Signs/signals • Law enforcement • *Public outreach*
24	**lack of visibility/glare/lighting**		• Specify/Design Glare Screen • Specify/Design Lighting • Specify/design reflectors • Accept risk and manage/control during construction phase		• Install glare screen • Install lighting • Ensure proper placement of portable lighting unit to prevent blinding and glare for motorists • *Communicate problems with DOT* • *Remove site obstructions*
25	**missing information (documentation of risk assessment); incomplete plans (TCP's); and incomplete bid requirements**			• Bid item identification • Preliminary plan review • Pre-bid meetings & communications	

Table 5.11.1h – Mitigations Strategies by Project Phase (hazard #27 thru #30)

		Mitigation Strategies by Project Phase			
	IDENTIFIED HAZARD	**PLANNING & PROGRAMMING**	**DESIGN**	**LETTING & AWARD**	**CONSTRUCTION**
26	**multiple prime in general proximity (resulting in discontinuous workzone signage & discontinuous traffic control)**		• Specify Contracting and Project Management responsibility • Specify Continuity of Traffic Control devices & signs • Accept risk and manage/control during subsequent phases	• Packaging of lettings to ensure continuity of work zone signage and project management responsibility	• Enforce Contracting and Project Management responsibility • Ensure Continuity of Traffic Control devices & signs • *Coordination traffic control with primes (between projects)* • *Communicate inadequacies w/ possible corrections*
27	**non-credible/non-current signs during interim season**			• Interim phase coordination – season to season signage during project transitions	• Remove non-credible signs (follow up with enforcement) • Signage and traffic control reviews (check credibility) • *Continuous or periodic monitoring on high volume projects* • *Communicate inadequacies w/ possible corrections*
28	**poor driver skills**		• Education • Training • Initiate smart work zone initiatives at letting	• Education • Training • Testing • Initiate smart work zone initiatives at letting	• Education • Training • Testing • Smart workzone initiatives
29	**poor visibility of workers**		• Project specification for worker safety training • Project Specification for high visibility worker apparel • Accept risk and manage/control during subsequent phases • *Consider lighting the area*		• Worker safety training • Enforce wear of high visibility worker apparel • *Back-up alarms* • *Ensure equipment and personal vehicles are not obscuring*

Table 5.11.1i – Mitigations Strategies by Project Phase (hazard #31 thru #33)

`		Mitigation Strategies by Project Phase			
	IDENTIFIED HAZARD	**PLANNING & PROGRAMMING**	**DESIGN**	**LETTING & AWARD**	**CONSTRUCTION**
30	**previous paint lines (confusion)**		• Specify effective removal techniques (sandblasting is preferred but causes other environmental issues *& may be restricted by specifications)* • Specify use of temporary pavement marking tape during staging • Accept risk and manage/control during construction phase		• Remove previous paint lines (sandblasting is preferred but causes other environmental issues) • Use temporary pavement marking tape in leiu of paint during staging • *Water blast* • *Re-pave roadway (min. depth)*

31	**railroads, pedestrian paths/travel routes & trail crossings**	• Integration with Third Parties (coordination)
		  ◦ ITS – Integrating Strategies (Intelligent Transportation Systems)
		• Accept risk and manage/control during subsequent phases
		  ◦ Final design phase (TCP's, etc.)
		  ◦ Construction phase (flaggers)
		• *Closure of paths/trails during construction*
			• Initiate coordination with local jurisdiction agreement and 3rd Party (railroad, etc.)
			• Design for Pedestrian protection (no standards yet – assign to contractors)
			• Integrate into the Design of Traffic Control Plans, etc.
			• Integration with Third Parties
			  ◦ ITS – Integrating Strategies (Intelligent Transportation Systems)
			• Accept risk and manage/control during subsequent phases
			  ◦ Construction phase(flaggers)
					• Coordination with 3rd Parties (railroad, etc.)
					• Monitor ITS effectiveness (deployment monitoring)
					• Monitor effectiveness of Traffic Control Plans.
					• Provided flaggers, etc. as needed
					• *Communicate inadequacies with possible corrections*
					• *Public/stakeholder engagement*

32	**road characteristics through the work zone (i.e., roadway classifications; narrow bridges; narrower shoulders; intersections; fore slopes; blind spots; line of sight obstructions; limited visibility due to topography)**		• Re-design – modify standard design when appropriate • Standards • Adjustments to standard documents • Engineering & design (widen, remove, modify) • Traffic control devices • Inform Motorist (signs, media, etc.) • Traffic Staging Plans (complex urban areas, etc) • Accept risk and manage/control during subsequent phases		• Inform motorist (signs, etc) • Employ Traffic Control Devices • Erect signs • Implement traffic staging plans • Field modifications (with approval) • *Communicate inadequacies with possible solutions* • *Remove site obstructions at merge or intersections*

Table 5.11.1j – Mitigations Strategies by Project Phase (hazard #34 thru #37)

		Mitigation Strategies by Project Phase			
	IDENTIFIED HAZARD	**PLANNING & PROGRAMMING**	**DESIGN**	**LETTING & AWARD**	**CONSTRUCTION**

33	**the condition of roadway & extra traffic volume of: detours; head-to-head traffic shifts; and shoulder shifts**	• Recon/drive detour to identify potential problems
		• Upgrade route prior to letting (if possible)
		• Accept risk and manage/control during subsequent phases
		  ◦ Design phase (road geometry/condition)
		  ◦ Construction phase (flaggers, pace vehicles, law enforcement)
			• Upgrade route prior to letting (if possible)
			• Re-design road geometry/condition
			• Accept risk and manage/control during subsequent phases
			  ◦ Construction phase (flaggers, pace vehicles, law enforcement)
			• *Consider traffic modeling and signage*
					• Flaggers
					• Pilot Cars
					• Law enforcement

34	**the points of merge**	• Accept risk and manage/control during subsequent phases
		  ◦ Design phase
		  ◦ Construction phase
			• Design points of merge for traffic & construction requirements
			• Develop techniques for implementing the merge area (painted pavement arrows & markings, etc)
			• Specify use of ITS (merge point ahead)
			• Accept risk and manage/control during subsequent phases
			  ◦ Construction phase
			• *Proper signing and coordination with public*
					• Monitor and adjust as necessary (flexibility provided in contract documents)
					• Utilize/employ ITS
					• *Advanced warning signs*
					• *Communicate inadequacies with possible corrections*

35	**the posted speed through the work zone**	• Policy Change
		• Accept risk and manage/control during subsequent phases
		  ◦ Design phase
		  ◦ Construction phase
			• Traffic Control Plans and designs to reduce speed
			• Accept risk and manage/control during subsequent phases
			  ◦ Construction phase
					• Law enforcement
					• Monitor traffic control affectiveness & modify as necessary
					• *ITS signage noting speed limit*

36	**the work zone area being laid out long before construction actually begins**			• Set contract period to reflect actual construction schedule (this prevents contractors from setting out the work zone to satisfy the contract but waits for construction to begin)	

Table 5.11.1k – Mitigations Strategies by Project Phase (hazard #38 and #39)

		Mitigation Strategies by Project Phase			
	IDENTIFIED HAZARD	**PLANNING & PROGRAMMING**	**DESIGN**	**LETTING & AWARD**	**CONSTRUCTION**
37	**too long of workzone length**				• Lane rental specifications • *Appropriate phasing* • *Limitations in the specs referencing length of closures* • *Reduce length and add additional warnings at 6 mile, 4 mile,& 2 mile*

38	**traffic congestion & delay through the work zone**	• Detours (& Alternate Routes)
		    • Off site
		    • On site
		• Road Closures
		• Lane Closures
		• Shoulder shift
		• Accelerated Project Completion Scheduling (to limit exposure of traveling public)
		• *Communicate with public*			

39	**traffic speed & speeding (i.e., excess traffic speed, and limited stopping distance)**		• Temporary signals
			• Project Specified Design Speed (advisory speed) – written in specs
			• Lane narrowing & barriers (design)
			• Speed cameras (written in specs)
			• Enforcement details in specifications
			• Policy enforcement
			• Accept risk and manage/control during subsequent phases
			    • Letting
			    • construction
				• Policy for adding extra enforcement
				• Legislation (such as fines double in work zones)
				• Manage During Construction Phase
					• Temporary Signals
					• Project Specified design speed
					• Lane narrowing
					• Speed Cameras
					• Law enforcement posted at critical timeframes (may cause other problems)
					• *Communicate inadequacies w/ possible corrections*
					• *ITS spped signs noting speed*

Mitigating strategies in Tables 5.11.1a thru 5.11.1k have been chronicled according to the hazards to which to pertain and the project phases where they can best be employed. Industry practitioners can use the listed strategies to develop a program for specific projects and/or can use these strategies as a basis for innovation.

5.5.6 Existing State of the Practice

Ultimately the results of the risk treatment/response section have chronicled the existing state of the practice for crash mitigation for work zones. It has also established the groundwork required to formalize the existing process into an integrated risk management approach that can be adopted by state highway agencies.

5.6 CHAPTER SUMMARY

This chapter utilized the methods described in the risk management model development process (Chapter 4) to identify, assess, and respond to specific risks, in particular the risk of vehicle crashes and fatalities in roadway work zones. The results of this section provided a list of identified hazards for each stage of the project development process; developed a method to assess hazards utilizing crash data provided from the Iowa Department of Transportation; and provided a list of possible mitigation strategies for each of the identified hazards that may be implemented in each phase of the project development process. Of the thirty-nine hazards that were identified, twenty two were assessed and quantified using data from the Iowa statewide crash data base for work zones. A combined risk score was determined by multiplying the severity ranking and the frequency ranking on the two dimensional risk matrix. The chapter concluded with the identification and listing of mitigation strategies for all phases of the project development process. The results have chronicled the existing state of the practice of crash mitigation that will serve as the first step in establishing a formal risk management program.

The following chapter will discuss the results, and make recommendations as to future research to be conducted either in the areas of innovation in work zone crash mitigation or construction risk management from the perspective of the stakeholders in each phase of the project lifecycle.

CHAPTER 6

CONCLUSIONS

6.1 INTRODUCTION

The goal of this research was to develop a method with which to mitigate work zone crashes and fatalities. This was accomplished through the creation of a formal risk management model that can be utilized during the construction management and administration of highway projects for all stages of the project lifecycle. This effort resulted in the development of an Integrated Risk Management Model as discussed in Chapter 4. This research consequently focuses on the standard risk management model for the identification, assessment, and response (treatment) of hazards that may increase either the frequency or severity of a vehicle crash in a work zone. The results of this research are presented by the three components of the standard risk management model. The first phase of this research was the identification of risks, the second phase was the assessment of risks, and the third phase was the identification of possible mitigation strategies. The tasks of the first phase and third phase were accomplished through the use of a comprehensive literature review, content analysis of papers and articles, focus group discussion, and internet surveys for the identification of work zone hazards and mitigation strategies. The tasks of the second phase were accomplished through the analysis of work zone crash database information and the development of a unique tool that allows for a qualitative assessment of hazards using quantitative data.

The following sections will discuss the findings of the three phases of this research, will make observations and recommendations based on these findings, and will discuss future research goals pertaining to work zone crash mitigation and the management of construction industry risks

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6.2 RISK POTENTIAL

The following section will discuss the results of the survey which was conducted during the identification of hazards phase and its comparison to the results of the database analysis. In order to prioritize the mitigation of potential hazards, the concept of "risk potential" must be explored. During the hazards assessment phase, a two dimensional risk matrix approach was developed in order to ascertain the relative frequency and severity of a specific work zone hazard (see Figure 6.2.1.). The risk matrix assigns a risk score to each hazard based on the product of the relative severity and relative frequency of a hazard. In Tables 5.8.6a-5.8.6c, hazards were assessed and given a severity rank, a frequency rank, and a risk score. Any risk/hazard that was given a rank of five in severity or frequency was color coded "red" to signify the need for an urgent response. Also, a hazard that received a risk score of 12 or greater was color coded "orange" or "red" to signify the need for an urgent or immediate response respectively. All other hazards were not color coded. However, it should be noted that any hazard that received a risk score between 8 and 10 possesses a moderate risk and should be given considerable attention when managing risks. Also for this research, any hazard that receives a ranking of "five" in either frequency or severity suggests a high severity or high frequency that would also pose a moderate risk of work zone crash.

FREQUENCY						
	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
		SEVERITY				

1 to 3	Low Risk Potential
4 to 6	Reduced Risk Potential
8 to 10	Moderate Risk Potential
12 to 15	Elevated Risk Potential
16 to 25	High Risk Potential

Figure 6.2.1 – Risk Assessment Matrix

The following sections provide a breakdown as to the risk potential of a hazard:

6.2.1 High Risk Potential

According to the precepts of this research, any hazard that received a risk score of sixteen or greater is in need of immediate risk attention. These hazards pose the greatest risk of vehicle crashes and fatalities to the work zone. Immediate attention must be made by all stakeholders during all phases of the project development process.

6.2.2 Elevated Risk Potential

For this research, any hazard that received a risk score between twelve and fifteen is in need of urgent risk attention. These hazards pose an elevated risk of vehicle crashes and fatalities to highway work zones. Urgent attention must be made by all stakeholders during all phases of the project development process.

6.2.3 Moderate Risk Potential

Any hazard that was given a ranking of five in either severity or frequency according to this research is considered a moderate risk and further attention should be given. All hazards that received a risk score between an eight and a ten should also be considered a moderate risk because the numerical combination of severity and frequency suggests that the hazard possesses a risk of a vehicle crash that is of the same distribution of all work zone crashes. Since the goal of this research is to reduce (mitigate) accidents and fatalities in work zones, any hazard that has been assessed between an eight and a ten must receive priority attention by all stakeholders during all phases of the project development.

6.2.4 Reduced Risk Potential

For this research, any hazard that received a risk score between four and six is in need of some risk attention. These hazards pose a risk of vehicle crashes and fatalities to highway work zones. However, the risk potential is slightly less than a "typical" hazard. Reasonable attention must be made by all stakeholders during all phases of the project development process.

6.2.5 Low Risk Potential

There really is no acceptable level when it comes to the risk of vehicle crashes, however, when evaluating hazards on a relative scale some of them carry a lower risk potential on the scale of hazards. Therefore, for this research, any hazard that received a risk score of three or lower poses a lower risk of vehicle crashes and fatalities in highway work zones than a “typical” hazard. Reasonable attention must be made by all stakeholders during all phases of the project development process.

6.3 FINDINGS

This section will deal specifically with the findings of the hazard identification phase and the findings of the risk assessment phase of this research. The risk response phase of this research compiled a consolidated list of mitigation strategies for each hazard during each phase of the project development process. Therefore, risk managers are presented with the opportunity to select from among the listed mitigation strategies or they may use other innovative methods to create a new strategy. For this reason, no further discussion is made about the possible treatment of risks associated with work zone crashes and fatalities.

During the first phase of this research, thirty-nine primary hazards where identified as having the potential to increase either the likelihood or severity of a vehicle crash in a roadway work zone. Of these hazards, twenty-two were found to correlate with data fields in the statewide crash database and were evaluated using fifty-six assessments of the statewide crash database. (Fifty-four of these assessments yielded usable output). The findings of the assessment phase revealed that three of the identified hazards had risk scores of sixteen; thirteen had risk scores between twelve and fifteen; twenty one had risk scores between eight and ten; thirteen had risk score between four and six; and four had risk scores lower than four. The following is a discussion of these findings.

6.3.1 Hazards of High Risk Potential

From the assessment portion of this research it was found that three hazards where identified with risk scores of “sixteen” (there were no hazards with a score greater than 16): #9) driver/operator unfamiliarity (out-of-state driver license); #10) Seasonal road use – June; and #10) seasonal road use – September.

Table 6.3.1 – Hazards with High Risk Potential

Hazards with High Risk Potential	Risk Score
#9) driver/operator unfamiliarity (out-of-state driver license)	16
#10) Seasonal road use – June	16
#10) seasonal road use – September	16

Driver/operator unfamiliarity

Over 90% of survey respondents acknowledged that “driver/operator unfamiliarity” could be identified and mitigated during the design, and/or construction phases of the project lifecycle. Therefore, there is general agreement between the expert panel, industry practitioners, and results from the database analysis that immediate attention must be given to “driver confusion from: driver/operator unfamiliarity” (particularly out-of-state motorists) where nearly 6% of all vehicle crashes involving drivers with out-of-state driver licenses are either fatal or serious injury crashes. This is greater than 4%, the overall percentage of crashes which result in fatal and serious injury. This resulted in an average severity ratio of 1.5 for “out-of-state driver” which ranked a “four” in terms of severity. Also, nearly 19% of all vehicle crashes involve drivers with out-of-state driver licenses. This ranked a “four” in terms of relative frequency, resulting in a risk score of “sixteen”. According to the premises of this research, more emphasis must be placed on methods to mitigate “driver confusion from: driver/operator unfamiliarity” (particularly out-of-state motorists). Some mitigation strategies are included in Table 5.11.1a- Table 5.11.1k of the results section (Chapter 5) of this research. Some of the identified mitigation methods include: positive control, education/information, media outlets, and employment of Intelligent Transportation Systems (ITS).

Seasonal road use

Over 90% of survey respondents acknowledged that “seasonal road use” could be identified and mitigated during the planning & programming, design, letting & award, and/or construction phases of the project lifecycle. There was also general agreement between the expert panel, industry practitioners, and results from the database analysis that immediate attention must be given to “extra traffic volume from seasonal road use” where nearly 6% of all vehicle crashes in June and September are either fatal or serious injury. This is greater than the 4% for all fatal and serious injury crashes. This resulted in an average severity ratio of 1.5 for both June and September which ranked a “four” in terms of severity. Also, nearly 13% of all vehicle crashes occur in June and 14% of all vehicle crashes occur in September. This ranked a “four” in terms of relative frequency for both June and September, resulting in a risk score of “sixteen” for each. It is presumed that the significance of June and September revolve around the beginning and end of the summer holiday as it relates to the academic school year as well as occurring during times of the busiest construction season. This research supports the view that more emphasis must be placed on methods to mitigate "extra traffic volume from seasonal road use." Some mitigation strategies are included in Table 5.11.1a- Table 5.11.1k of the results section (Chapter 5) of this research and include: construction schedule, planning calendars, work/equipment limitations/restrictions spelled out in contract, coordination meetings, and restricted construction activities. However, innovation will be the greatest asset in the mitigation of this hazard.

Table 6.3.2 – Hazards with Elevated Risk Potential

Hazards with Elevated Risk Potential	Risk Score
#9) inadequate/confusing traffic control (no controls present)	12
#17) Lane Closures	12
#17) lane shift/cross over (head-to-head)	12
#18) commercial trucks	12
#24) hours of dark; roadway not lighted	15
#28) poor driver skills(operator error)	12
#34) the points of merge	12
#35) the posted speed (65 mph)	15
#35 the posted speed (55-60 mph)	12
#12) high risk traffic – Wednesday	12
#12) high risk traffic – Thursday	12
#12) high risk traffic – Friday	12
#10) seasonal road use – July	12

6.3.2 Hazards of Elevated Risk Potential

From the assessment portion of this research it was found that thirteen hazards obtained a risk score between twelve and fifteen: (1)#9) inadequate/confusing traffic control (no controls present); (2) #17) lane closures; (3)#17) lane shift/cross over; (4)#18) commercial trucks; (5)#24) roadway not lighted; (6)#28) poor driver skills(operator error); (7)#34) the points of merge; (8)#35) the posted speed (65 mph); (9)#35 the posted speed

(55-60 mph); (10)#12) high risk traffic – Wednesday; (11)#12) high risk traffic – Thursday; (12) high risk traffic – Friday; and (13)#10) seasonal road use – July.

Inadequate/confusing traffic control

Over 90% of survey respondents agreed that “inadequate/confusing traffic control” could be identified and mitigated during the design, and/or construction phases of the project lifecycle. Therefore, there is general agreement between the expert panel, industry practitioners, and results from the database analysis that urgent attention must be given to “driver confusion from: inadequate/confusing traffic control” (particularly no controls present), as nearly 4% of all vehicle crashes which occur where no controls are present are either fatal or major injury. This is roughly the same as the 4% of all crashes which result in fatal and serious injury. This resulted in an average severity ratio of 0.9 with rounding which ranked a “three” in terms of severity. However, nearly 47% of all vehicle crashes occur where no controls are present. This ranked a “four” in terms of relative frequency, resulting in a risk score of “twelve.” More emphasis must be placed on methods to mitigate “driver confusion from inadequate/confusing traffic control. Some identified mitigation strategies which are included in Table 5.11.1a- Table 5.11.1k of the results section of this research include: upgrade modify conditions/geometry, design and employ traffic control plans, and utilize media outlets to provide information/education.

Increased demand, inadequate capacity, and confusing layout

Over 80% of survey respondents confirmed that "increased demand, inadequate capacity, confusing layout of: detours, and closures (road & lane)" could be identified and mitigated during the design, and/or construction phases of construction projects. This general agreement between the expert panel participants, industry practitioners, and results from the database analysis support that urgent attention must be given to "lane closures" and "lane shift/crossover (head-to-head traffic)" where nearly 5% and 6% of all vehicle crashes which occur in areas of "lane closures" and "lane shift/crossover (head-to-head traffic)" respectively, are either fatal or major injury crashes. These are greater percentages than the 4% of overall crashes which result in fatal and serious injury. This resulted in an average severity ratio of 0.9, with rounding, which ranked a "three" in terms of severity for "lane closures" and an average severity ratio of 1.6, with rounding, which ranked a "four" in terms of severity for "lane shift/crossover". However, nearly 46% of all vehicle crashes occur in areas of "lane closures" and 12% of all vehicle crashes occur in areas of "lane shift/crossover (head-to-head traffic)" these resulted in a ranking of "four" and "three" respectively in terms of relative frequency. Therefore, both of these hazards resulted in a risk score of "twelve." These results indicate that more emphasis must be placed on methods to mitigate the increased demand, inadequate capacity, and confusing layout of: detours, and closures (road & lane). Some mitigation strategies were included in Table 5.11.1a- Table 5.11.1k of the results section of this project. These include: design/employ positive control - updated MUTCD, education/information, employment of Intelligent Transportation Systems (ITS), and changeable message signs.

Increased number of commercial trucks

Survey respondents generally acknowledged that "increased number of commercial trucks on existing routes or alternate routes" is a hazard which could be identified and mitigated during the various project phases. The percentage of respondents who agreed varied by project phase: planning & programming (50% of survey respondents), design (80%), and/or construction phases (50%). This supports that there is some disagreement between the expert panel, industry practitioners, and results from the database analysis concerning the extent to which commercial vehicles contribute to work zone crashes. This is especially true with industry professionals in the planning and programming and construction phases. A greater percentage of respondents felt that commercial truck traffic could be a concern for mitigation in the design phase. This disagreement may be because of the wording of the survey question, or respondents may feel that there little that can be done in each project phase to address commercial trucks. However, the results of the analysis show that urgent attention must be given to "commercial trucks" as nearly 8% of all vehicle crashes involving vehicles with a commercial vehicle configuration result in a fatal or major injury. This is roughly twice the 4% of overall vehicle crashes which result in fatal and serious injury. This resulted in an average severity ratio of 2.1, with rounding, ranking "increased number of commercial trucks on existing routes or alternate routes" as a "four" in terms of severity. Additionally, nearly 10% of all vehicle crashes involve a commercial truck. This ranked a "three" in terms of relative frequency, resulting in a risk score of "twelve". This finding supports the concept that more emphasis must be placed on methods to mitigate the number of commercial trucks in work zones. Some mitigation strategies were included in

Table 5.11.1a- Table 5.11.1k of the results section of this project. These mitigation strategies include: detour signage; possible parallel route reviews; specification of commercial vehicle routes; the use of signage to acknowledge the existence of commercial trucks; awareness initiatives; speed control; driver training; and rumble strips.

Lack of visibility/glare/lighting

Over 80% of survey respondents acknowledged that "lack of visibility/glare/lighting (dark-roadway not lighted)" could be identified and mitigated during the design, and/or construction phases of a roadway project. Therefore, there is general agreement between the expert panel, industry practitioners, and results from the database analysis that urgent attention must be given to "lack of visibility/glare/lighting" as nearly 10% of all vehicle crashes which occur in periods of darkness when the roadway is not lighted are either fatal or serious injury. This is more than twice the 4% of all crashes which result in fatalities or serious injury. This produced an average severity ratio of 2.8, which ranked a "five" in terms of severity. Additionally, nearly 6% of all vehicle crashes occur in the dark when the roadway is not lighted. This ranked a "three" in terms of relative frequency, resulting in a risk score of "fifteen". This finding indicates a need for more emphasis to be placed on methods to mitigate the lack of visibility/glare/lighting in work zones. Some mitigation strategies were included in Table 5.11.1a- Table 5.11.1k of the results section of this work and include: specify/design work zone lighting, specify/design reflectors, ensure proper placement of lighting, and communicate any problems with the DOT.

Poor driver skill:

Less than 30% of survey respondents acknowledged that “poor driver skills (operator error)” could be identified and mitigated during design, letting & award, and/or construction. There is general disagreement between the expert panel, industry practitioners, and results from the database analysis that urgent attention must be given to “poor driver skills” where approximately 5% of all vehicle crashes involving operator error are either fatal or serious injury. This is slightly more than the 4% for all fatal and serious injury crashes. With rounding this resulted in an average severity ratio of one which ranked a “three” in terms of severity. Additionally, nearly 25% of all vehicle crashes occur as a result of operator error. This ranked a “four” in terms of relative frequency, resulting in a risk score of “twelve.” The general disagreement of survey respondents may stem from the idea that the respondents feel that mitigation of this hazard should be done outside of the project development. Driver skills are an important and urgent work zone hazard that must be mitigated and than more emphasis must be placed on innovative methods to mitigate poor driver skills in work zones. Some mitigation strategies which can be included in the development of roadway construction projects are included in Table 5.11.1a- Table 5.11.1k of the results section of this work and include: education, training, testing, and smart work zone initiatives. This is an area where other innovative strategies can be explored to reduce the likelihood and severity of crashes resulting from driver error.

Points of merge

Depending on the project phase, between 50% and 80% of survey respondents acknowledged that "the points of merge" could be identified and mitigated during the planning & programming, design, and/or construction phases. There is general agreement between the expert panel, industry practitioners, and results from the database analysis that urgent attention must be given to "the points of merge" where approximately 5% of all vehicle crashes that occur in merge points are either fatal or serious injury. This is slightly more than the 4% for all fatal and serious injury crashes. With rounding this resulted in an average severity ratio of one which ranked a "three" in terms of severity. Additionally, nearly 32% of all vehicle crashes occur as a result of "points of merge". This ranked a "four" in terms of relative frequency, resulting in a risk score of "twelve". This risk score indicates the necessity of placing more emphasis on the points of merge for work zones. Some mitigation strategies which are included in Table 5.11.1a- Table 5.11.1k of the results section of this study include: development of techniques for implementing merge areas, specification/employment of ITS, advance warning signs, and provision for flexibility in specifications to monitor and adjust as necessary.

Posted speed through the work zone

Most of the survey respondents acknowledged that "the posted speed through the work zone" could be identified and mitigated during planning & programming, design, and/or construction phases, respectively. There is general agreement between the expert panel, industry practitioners, and results from the database analysis. The results of the analysis show that urgent attention must be given to “the posted speed” as nearly 11% of all vehicle crashes that occur in 65 mph and 6% occur in 50-60 mph work zones result in fatal or major injury. These are roughly 1.5 to three times the 4% overall rate of fatal and serious injury related crashes. This results in an average severity ratio of 2.7 for 65 mph posted speed and 1.4 for 50 to 60 mph posted speed. This results in a severity rank of “five” and “three” for posted speeds of 65 mph and 50 to 60 mph respectively. Additionally, nearly 6% of work zone crashes occur in 65 mph posted zones and 37% of work zone crashes occur in 50 to 60 mph work zones. These ranked a “three” (65 mph) and a “four” (50-60 mph) in terms of relative frequency, resulting in a risk score of “fifteen” (65 mph) and “twelve” (50-60 mph). Thus work zone safety would likely improve if more emphasis were to be placed on innovative methods to mitigate the number of vehicle crashes in speed zones greater that 50mph. Some mitigation strategies which are included in Table 5.11.1a- Table 5.11.1k of the results section of this project include: policy changes, traffic control plans and designs, ITS signage noting speed limit and law enforcement.

High risk traffic

Over 60% of survey respondents acknowledged that “high risk traffic” could be identified and mitigated during design, letting & award, and/or construction. Therefore, there is general agreement between the expert panel, industry practitioners, and results from the database analysis that urgent attention must be given to mitigating strategies which consider “the day of the week” as between 4% and 5% of all vehicle crashes that occur Wednesday, Thursday and Friday are either fatal or serious injury crashes. These are generally the same as the 4% for all fatal and serious injury crashes, resulting in an average severity ratio between 0.9 and 1.2 which ranked a "three" in terms of severity for each of these days of the week (Wednesday, Thursday and Friday). Additionally, 17% to 18% of all vehicle crashes occur on Wednesdays, Thursdays and Fridays. All three ranked a "four" in terms of relative frequency, resulting in risk scores of "twelve" for each work day. It is the view of this research than more emphasis must be placed on developing innovative methods to mitigate the vehicle crashes that occur on Wednesday, Thursday, and Friday in work zones. Some mitigation strategies which were included in Table 5.11.1a- Table 5.11.1k of the results section include: development of work day restrictions, limits to the contract, coordination meetings, and law enforcement. Additional research should also look at time of day affects on traffic crashes.

Seasonal road use

Finally, over 90% of survey respondents acknowledged that "seasonal road use" could be identified and mitigated during planning & programming, design, letting & award, and/or construction. There is also general agreement between the expert panel, industry practitioners, and results from the database analysis that urgent attention must be given to "extra traffic volume from seasonal road use" where nearly 5% of all vehicle crashes in July are either fatal or serious injury. This is greater than the 4% for all fatal and serious injury crashes. This resulted in an average severity ratio of 0.9 for July which ranked a "three" in terms of severity. Also, nearly 13% of all vehicle crashes occur in July. This ranked a "four" in terms of relative frequency, resulting in a risk score of "twelve". It is presumed that the significance of July revolves around the middle of the summer holiday as it relates to the academic school year as well occurring during a time frame where the construction season is most busy. More emphasis must be placed on methods to mitigate "extra traffic volume from seasonal road use." Some mitigation strategies were included in the results and include: revisions of construction schedules, planning calendars, work/equipment limitations/restrictions spelled out in contract, coordination meetings, and restricted construction activities. However, innovation will be the greatest asset in the mitigation of this hazard.

6.3.3 Hazards of Moderate Risk Potential

From the perspective of this research a hazard that has a risk score between 8 and 10 is considered to have a moderate risk potential. Additionally, hazards that have a high rank of "five" in either the severity or frequency calculation, are considered to pose a moderate risk. From the assessment portion of this research it was found that no hazard obtained a relative frequency rank of five, however, seven obtained a severity rank of five. Two of these hazards were identified earlier as having an elevated risk potential: (1) #24) lack of visibility/glare/lighting (dark roadway not lighted); and (2) #31) the posted speed through the work zone (65 mph). The five remaining hazards with a severity score of "five" are: (1) #4) construction vehicle traffic - flatbed; (2) #28) poor driver skills (aggressive driving); (3) #29) poor visibility of workers (workers involved in crash); (4) #31) railroads; and (5) #39) traffic speed and speeding.

Table 6.3.3 – Hazards with Moderate Risk Potential due to High Severity Ranking

Hazards with Moderate Risk Potential due to Severity Rank of "5"	Risk Score
#4) construction vehicle traffic - flatbed	10
#28) poor driver skills (aggressive driving)	10
#29) poor visibility of workers (workers involved in crash)	5
#31) railroads	5
#39) traffic speed and speeding	10

All but one of the five hazards was in general agreement in terms of focus group, survey respondents, and database analysis. The four hazards which were in general agreement are: (1) #4) construction vehicle traffic - flatbed; (2) #29) poor visibility of workers (workers involved in crash); (3) #31) railroads; and (4) #39) traffic speed and speeding. Therefore, only the hazard that is in general disagreement— #28) poor driver skills (aggressive driving—will be discussed. As mentioned earlier, there is some disagreement between the focus group, survey respondents, and database analysis for the hazard of "poor driver skills." This may be the case since many construction industry professionals see driving skills as an area generally out of their immediate influence. However, just as the case with "operator error", "aggressive driving" has shown to have a relatively high average severity ratio of 2.8 this ranked a "five" in terms of severity and has a risk score of "ten", both of which make "poor driver skills – aggressive driving" a moderate risk. In any case, more emphasis must be placed on innovative methods to mitigate "operator error." As mentioned earlier, some mitigation strategies are presented in the results section of this work; however, work zone safety will greatly benefit form more future research in this area.

6.4 RESEARCH LIMITATIONS

As mentioned throughout this dissertation, the purpose of this research is to develop tools to identify, assess, and respond to the risks associated with work zone vehicle traffic. Therefore, methods and tools were created to assist decision makers, planners and designers with their risk management responsibilities with the intention of keeping the process simple and easy to use. However, the designed simplicity also has some limitations. The proposed assessment tools are intended to assist with prioritizing work zone related risks. Once a potential risk has been identified it will require additional analysis in order to determine all the contributing factors associated with a particular risk by utilizing any and all applicable models. This research is limited in its ability to account for multiple variables contributing to work zone crashes. Researchers have developed work zone analysis tools (Bai 2007, Li 2008), which may be useful in the application of multi-variate analysis and it is a recommendation of this research to implement such tools to make greater strides in the area of multi-variate analysis of work zone hazards and risks. The tools developed through this project do not attempt to predict types or numbers of work zone crash incidents to a statistical significance; this project provides the framework for risk managers to assess risks on a project specific level.

6.5 FUTURE RESEARCH

As a follow-up to the results of this research project, it is suggested that the following be considered as recommendations for further research in the area of construction project lifecycle analysis, and risk management:

1- More queries and data mining on the list of 39 hazards of this research using the approach of this research. For instance, time of day, principal driving holidays, and such should be assessed.

2- Build on the methodologies described in this research to conduct multivariate risk assessments to determine the effect on frequency and severity when multiple hazards contribute to a work zone crash.

3- Expand the scope of this research by reviewing a sampling of actual accident reports for crash characteristics and information not available in the crash database.

4- As also recommended by University of Kansas (Bai, 2007), extend this study to include Department of Transportation crash data from various other states.

5- Evaluate hazards that could not be assessed by using the database, by utilizing the approach employed by Shen (2001) that uses survey responses to qualitatively assess uncertainty in construction projects. This recommendation is consistent with future research needs discussed by Zou (2006).

6- Conduct research to develop a holistic risk management model to investigate all other transportation related risks with which agencies, departments and organizations are exposed.

7- Expand the scope of this project by conducting research on the work zone jobsite that addresses jobsite safety risks – not related to the traveling public.

8- Expand the nature of this research for the implementation and evaluation of a risk management program by the Iowa Department of Transportation.

9- Develop an automated method to manage work zone vehicle crash risks, based on the automated method of assessing scheduling risks presented by Schatterman, (2008) using a database that is created and maintained using the methods and results of this research.

10- Test the generalizability of the integrated model by utilizing the tools, methods and approach of this research to create a formal integrated risk management model for general construction and mining operations by assessing and evaluating the accident reports and databases maintained by OSHA (Occupational Safety and Health Administration) and MSHA (Mine Safety and Health Administration).

11- Conduct research as to the state of the practice for SHA in terms of lifecycle or the project development process of highway/roadway projects. This will facilitate the development of a project management function that would thereby implement a formal risk management program. Without an existing project management program, it is nearly impossible to adopt an integrated risk management program.

12- Develop a case study approach to apply, document, and assess the integrated risk management program inside an organization and on a project-specific basis.

13- From the results of this research more attention and innovation needs to be addressed in the areas of:

    a. Creating adjustments to the investigating officer's crash report that explicitly document the hazards and factors associated with work zone crashes.

    b. Development of a near-miss reporting structure that can gather incident data from the view point of a bystander, potential victim of a crash, and the individual who nearly caused a crash.

    c. Development of an accident/near miss log that is maintained by the project management team.

d. Development of innovative methods to conduct driver training. This should be an ongoing process that takes into account driver skill development and maturity. This could possibly be incorporated as an extension of the current driver license renewal process.

6.6 CHAPTER SUMMARY

Chapter 4 of this work contains a framework of an integrated risk management model. This model is intended for the seamless integration into an existing management system. In order to fully integrate a risk management program into an organization, a full project management program must already be in place where the next logical step is to integrate a risk management ideology. The essence of a risk management program is the standard risk management model as described in chapter 2 and 4, where the impetus is: risk identification, risk assessment, and risk response (treatment). The results section of this dissertation contains information pertaining to the identification, assessment, and possible mitigation strategies for work zone hazards. Not all hazards are easily quantifiable by the use of database analysis. More research needs to be conducted qualitatively to assess hazards that possess a degree of uncertainty.

APPENDIX A. SAMPLE RISK MANAGEMENT POLICY STATEMENT

Oadby & Wigston Borough Council

Risk Management Policy Statement

August 2006

The risk management policy of Oadby & Wigston Borough Council is to adopt best practices in the identification, evaluation and cost effective control of risks to ensure that they are eliminated or reduced to an acceptable level.

All members and employees should understand the nature of risk and accept responsibility for risks associated with their area of authority. The risk management objectives of the Council are to:

- Integrate risk management into the culture of the organisation
- Manage risk in accordance with best practice
- Fully document major threats and opportunities
- Clearly identify risk exposures
- Implement cost effective actions to reduce risks
- Ensure conscious and properly evaluated risk decisions

These objectives will be achieved by:

- Establishing a risk management organisational structure to act in an advisory and guiding capacity which is accessible to all employees
- Including risk management as an agenda item at meetings of the Management
- Team and Policy & Resources Committee as appropriate
- Providing risk management awareness training
- Embedding risk management principles into the various decision making processes
- Maintaining appropriate incident reporting and recording systems with investigation procedures to establish cause and prevent recurrence
- Maintaining effective communication both within the Council and with the Council's external stakeholders
- Monitoring arrangements for the management of risk on an ongoing basis

The Strategic Risk Management Group will be responsible for developing specific procedures for risk management activities. This group will be supported by the Operational Risk Management Group.

Role of the Strategic Risk Management Group

The group will provide control and support of risk management activities by:

- Preparing and recommending changes to the risk management strategy
- Identifying and assessing risks
- Preparing, monitoring and reviewing the risk register
- Recommending action to address risks
- Reporting key risks to the Council's Management Team and Policy & Resources Committee
- Arranging/providing risk management training as appropriate
- Advising and supporting the Operational Risk Management Group

Role of the Operational Risk Management Group

The group will:

- Identify and assess operational risks
- Consider and recommend the insurance requirements of the Council
- Review insurance claims and recommend measures to reduce the likelihood of
- future claims
- Review accident reports and health and safety records and recommend
- improvements to procedures
- Identify hazards within the working environment and in areas accessible to
- customers and recommend corrective action
- Identify the operational risks arising from new legislation, guidance and working
- directives
- Raise awareness of risk management amongst all employees

Oadby & Wigston Borough Council
Risk Management Strategy
August 2006

1. Introduction

Risk management at Oadby & Wigston Borough Council is all about managing our threats and opportunities. By managing our threats effectively we will be in a stronger position to deliver our objectives. By managing our opportunities well we will be in a better position to provide improved services and better value for money.

In this strategy 'risk' is defined as something happening that may have an impact on the achievement of our objectives. When our management of risk goes well it often remains unnoticed. When it fails, however, the consequences can be significant and high profile. Effective risk management is needed to prevent such failures.

A risk management strategy is an essential element of strategic planning. The Council has a corporate plan covering the whole of the Council's activities and the risk management strategy should be seen as sitting under this broader umbrella.

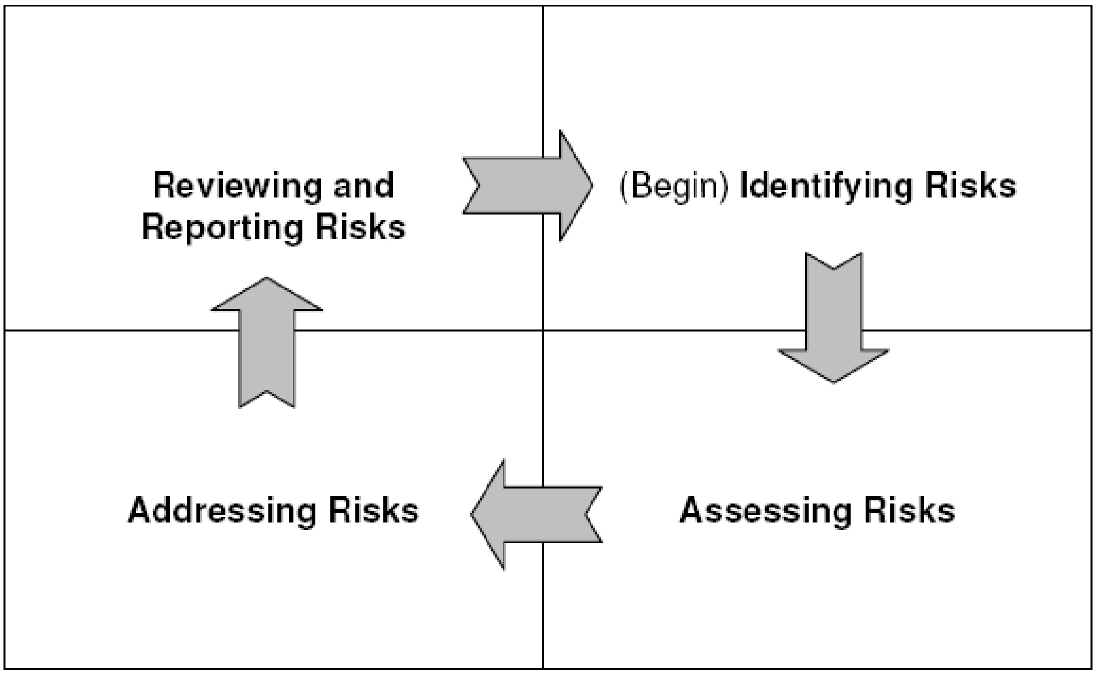
This risk management strategy describes the processes that the Council will put in place and link together to identify, assess, address and review and report on our risks. The strategy provides the framework for the management of risk across the whole Council.

Overall, the goals of our risk management strategy are to have procedures in place to:

- Integrate risk management into the culture of the organisation
- Manage risk in accordance with best practice
- Fully document major threats and opportunities
- Clearly identify risk exposures
- Implement cost effective actions to reduce risks
- Ensure conscious and properly evaluated risk decisions

2. Principles and Implementation

The four linked elements of the strategy – identifying, assessing, addressing and reviewing and reporting on our risks are illustrated below and described in the following sections of this strategy.



Principles

Transparent, co-ordinated, publicly credible and effective – these are the four key principles that will underpin the Council's Risk Management Strategy. As we implement the strategy we will seek to embed these in the culture of the organisation. Managers will need to view risk management as an integral part of their job and the Council's management team will keep the top risks faced by the Council under regular strategic review. Risk management will only become common practice if there is a better understanding of what it involves and the benefits that it can help to secure in terms of achieving the Council's objectives. We will maintain a proactive approach to risk management, which ensures that less time is spent reacting to situations and more time is spent taking advantage of opportunities.

Transparent

We will be open in our approach to managing risks. Employees, outside organisations and members of the public should expect to have access to information on our current risks and how we are managing them.

Co-ordinated

We will be consistent in how we assess and manage our risks throughout the organisation. We will identify risk owners for both specific and cross-cutting risks.

Publicly Credible

We will seek to gain public trust in the policy areas for which we have responsibility by following and communicating a precautionary approach when making major decisions. We will take proportionate actions when addressing risk – the cost and time of our efforts should be in balance with the potential impact of the risk, both in the short and the long term.

Effective

We will have a robust approach to risk management – aiming to identify, assess, address and review and report on risk in a way that can stand audit scrutiny, building on best practice and protecting the interests of our stakeholders.

Implementation

We will develop the Council's website so that stakeholders, including members of the public, can obtain information on our approach to risks.

We will conduct appropriate training to promote the awareness of risk management throughout the Council. Such training will include advice to policy makers on dealing with risk-related issues in policy development and advice to operational managers in identifying and working with risks on a daily basis.

3. Identifying Risks

A risk is something, which may have an impact on the achievement of our objectives. It may come from outside the Council (for example, as a result of new legislation) or inside (for example, as a result of initiative overload).

Risks will be assessed in terms of how likely they are and the magnitude of the consequences if they were to occur. The modern view of business risk and one that the Council aims to encourage, views many risks as opportunities to be embraced rather than threats to be avoided.

The Council will identify both strategic and operational risks and will establish an appropriate organisational structure to facilitate this process.

The Council's Strategic Risk Management Group made up of senior officers of the Council and led by the Director of Resources will be responsible for identifying, assessing and monitoring key risks. A member risk management champion will be appointed.

Once risks have been identified, we will capture essential information about them in the Council's risk register. This is a key building block of our strategy. The register should be a working document and a key source of information for the efficient and effective provision of Council services. The process must not however be allowed to become over bureaucratic.

We recognise that the identification of risks is an ongoing task. All members and employees have a part to play – it is not the sole domain of managers or the Council's management team.

4. Assessing Risks

To assess risks we will identify the consequences of a risk materialising and give each risk a score or *risk rating*. The initial assessment will be refined by the Strategic

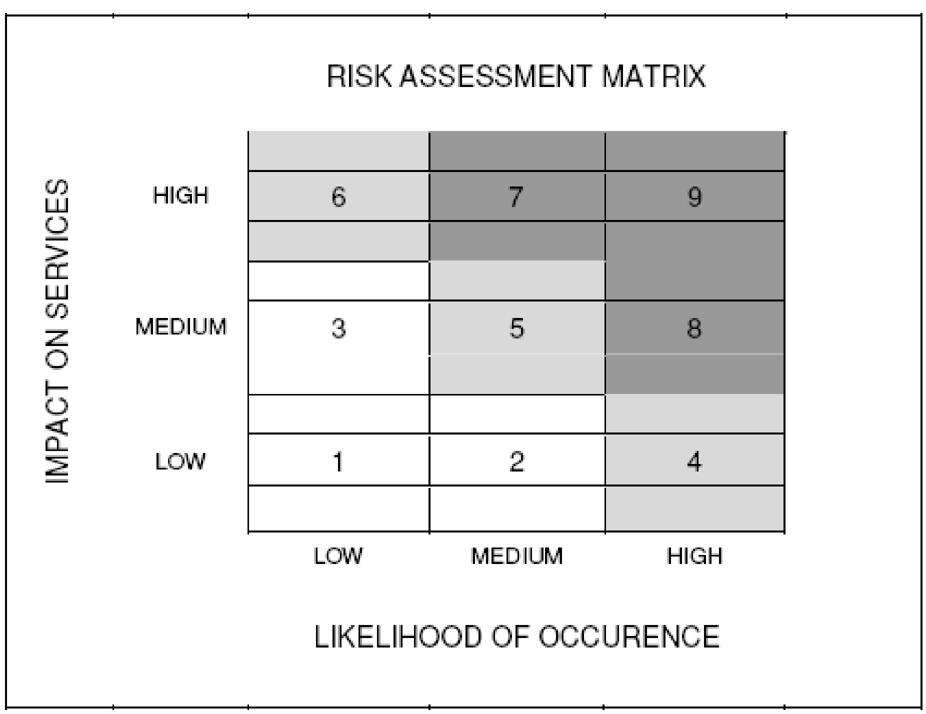
Risk Management Group and a risk owner will be identified who will be responsible for reviewing and accepting the assessment that will feed into the risk register.

Risk Rating

We need to have some means of comparing our risks so that we can concentrate our efforts on addressing those that are most important. We will use the standard approach of giving each risk a relative score, depending on a combination of its likelihood and its impact as shown below.

Risk Assessment Matrix

Risk Assessment Matrix



Methods for assessing the likelihood of occurrence and the impact on Council business are not specifically defined due to the different types of risks facing the Council. Definitions will however develop as the risk management strategy develops. The significance of the scores within the risk assessment matrix will be further enhanced by using a 'traffic light' colour coding system. Risks within the 3 top right hand squares of the matrix will be coded red. The 3 bottom left hand squares will be coded green. The squares in between will be coded amber. The Council's management will focus their attention on the 'red risks'.

The Council's management team will take a strategic view of its risks. They will receive a report on key risks on a quarterly basis and assess these risks against the high-level objectives and priorities of the Council.

5. **Addressing Risks**

Having properly identified and assessed our risks, we will select one of the following approaches (the four T's):

Transfer the risk: this might be done through such arrangements as conventional insurance or by asking a third party to take on the risk in another way.

Tolerate the risk: our ability to take effective action against some risks may be limited, or the cost of taking action may be disproportionate to the potential benefit gained. In this instance, the only management action required is to 'watch' the risk to ensure that its likelihood or impact does not change. If new options arise, it may be appropriate to treat this risk in the future.

Treat the risk: the purpose of treatment is not necessarily to terminate the risk but, more likely, to set in train a planned series of mitigation actions to contain the risk to an acceptable level.

Terminate the risk: this involves decisive action to eliminate a risk altogether. However, risk owners need to be aware that the action taken could introduce new risks to be addressed.

6. **Reviewing and Reporting Risks**

Appropriate and effective review and reporting arrangements will reinforce and support our risk management activities. This will allow up-to-date and accurate performance information to be passed to risk owners and senior managers.

We need evidence that our management interventions are having the desired outcome on our risks. The risk register is one of the basic building blocks of our strategy and we will ensure that this is a ‘living document’ which risk owners should monitor and review on an ongoing basis.

In addition to the ongoing identification and monitoring of risks, an annual assessment of the effectiveness of the process will be included in the Council’s Statement on Internal Control reported to Policy & Resources Committee.

APPENDIX B. FOCUS GROUP PARTICIPANT EMAIL LETTER

Greetings to All,

The Iowa State University research team has come to the point in our highway research project to solicit your help in some specific areas (see expert panel objectives). It is our desire to conduct an expert panel discussion in Ames sometime in the near future (late September, early October).

Research Goal: Create a formal risk management model to be utilized during the construction management and administration of highway projects in order to mitigate work zone accidents and fatalities.

Research Focus: The focus of this research project is on risk management and project planning.

The intent of this research project is to create/provide a formal process of risk management for all stages of the construction project life cycle.

Expert Panel Objectives:

1. Create the framework for an integrated risk management model
2. Identify activities, tasks and considerations associated with each stage of a typical project
3. Identify stakeholders for each stage of a typical project
4. Create a checklist of potential hazards/risks (related to work zone accidents) that are typically associated with each stage of the project.
5. Create a list of possible strategies to manage each of the identified hazards/risks for each stage of the construction project life cycle.

In confirming receipt of this email please reply with your name, title, area of expertise, and organization. (This information will be used in the report to show the wide range of experience and qualifications of the expert panel). Also, please indicate if you are willing to travel to Ames, Iowa for the panel discussion or if you require remote access to the discussion.

Thank you for your time and effort and we look forward to working with you.

Best Regards,

Dan Enz

APPENDIX C. FOCUS GROUP WORKSHEET/RESULTS

STAGE 4-A: RISK MANAGEMENT CHECKLIST – PLANNING & PROGRAMMING PHASE

PLANNING & PROGRAMMING	PRELIMINARY DESIGN	FINAL DESIGN	LETTING & AWARD	CONSTRUCTION

	What are the planning activities associated with each project phase?	Who should be part of the risk management team for each project phase? (Stakeholders)		What are the potential hazards associated with each planning activity? (check list)		What are some mitigation strategies for these hazards?
Major Activities:	**Activity Considerations**	**Stakeholders**		**Potential Hazards**	**FACTORS**	**Mitigation Strategies**
Planning	Determine Purpose and Needs • Existing conditions • Future requirements • Time (Urgency) • Schedule • Safety needs • Type of Project o Bridge replacement o Full depth pavement replacement o Asphalt overlays • Merge Points • Lane Capacity Improvement or Requirement Studies • Feasibility study • Route study • Corridor study • Subarea study • Major Investment Study (MIS) • Value Engineering study Environmental Considerations • Environmental documentation Interagency Coordination	➢ Department of Transportation ➢ Systems planning ➢ District Engineer (lead PMT) ➢ OLE ➢ Traffic & Safety ➢ ROW ➢ Bridge ➢ Elected Officials ➢ Consultants ➢ Contractors and construction managers ➢ Zoning authorities/local jurisdictions ➢ Transportation authorities ➢ MPO/RPA ➢ Health and Safety Authorities ➢ Local Business owners ➢ Architect/Engineer ➢ Financial & legal advisors ➢ Property Owners ➢ Commuters ➢ Third Party ➢ Law Enforcement ➢ Emergency Response ➢ Media ➢ Schools ➢ Railroad ➢ Utilities ➢ Large Employers (large traffic generators)	1A-DC	➢ Build/Rebuild under traffic	➢ WORKZONE CONDITION	➢ Control Risk during subsequent phases • Design phase (construction phasing for demo work,etc.) • Construction phase
			2A-DC	➢ Falling Debris/material • Overhead structures repair/replacement • Blasting	➢ WORKZONE CONDITION	➢ Detours (off site) ➢ Road Closures ➢ Lane Closures ➢ Control Risk during subsequent phases • Construction phase (scheduling)
			10A	➢ Traffic Congestion & Delay through workzone	➢ OPERATING ENVIRONMENT	➢ Detours (& Alternate Routes) • Off site • On site ➢ Road Closures ➢ Lane Closures ➢ Shoulder shift ➢ Accelerated Project Completion Scheduling (to limit exposure of traveling public)
			3A-DLC	➢ Extra traffic volume through workzone • Construction traffic • Events • Holidays • Seasonal traffic/road use	➢ OPERATING ENVIRONMENT	➢ Control Risk during subsequent phases • Design phase (alignment, geometry, etc.) • Final Design (schedule, standard specs, etc.) • Letting & Award phase (construction schedule) • Construction phase (Construction Scheduling)
			4A-DC	➢ Detour/Head-to-Head traffic shift/Shoulder Shift • Condition of roadway • Extra traffic volume	➢ ROAD CHARACTERISTICS • Road condition • Road geometry • Road type	➢ Recon/drive detour to identify potential problems ➢ Upgrade route prior to letting (if possible) ➢ Control Risk during subsequent phases • Design phase (road geometry/condition) • Construction phase (flaggers, pace vehicles, law enforcement)
			5A-D C	➢ Posted Speed Through WorkZone	➢ WORKZONE CONDITION	➢ Policy Change ➢ Control Risk during subsequent phases • Design phase • Construction phase
			6A-DC	➢ Points of Merge	➢ WORKZONE CONDITION	➢ Control Risk during subsequent phases • Design phase • Construction phase

	What are the planning activities associated with each project phase?	Who should be part of the risk management team for each project phase? (Stakeholders)		What are the potential hazards associated with each planning activity? (check list)		What are some mitigation strategies for these hazards?
Major Activities:	**Activity Considerations**	**Stakeholders**		**Potential Hazards**	**FACTORS**	**Mitigation Strategies**
			7A-DC	➢ Accelerated project completion • Overexposure of workers • Inclement weather construction • External construction completion date requirement (harvest, overlay cure, etc.)	WORKZONE CONDITION OPERATING ENVIRONMENT	➢ Material Selection to minimize construction duration • PCC/ACC, etc. • Full Depth vs. Overlay ➢ Control Risk during subsequent phases • Design phase • Construction phase
Programming	Selecting & Prioritizing projects Environmental Determination Schematic Development Public Hearings ROW plan Project Funding	➢ Department of Transportation ➢ Program management	8A-D C	➢ Railroads, Pedestrian Paths/travel routes & Trail Crossings	➢ OPERATING ENVIRONMENT	➢ Integration with Third Parties (coordination) • ITS – Integrating Strategies (Intelligent Transportation Systems) ➢ Control Risk during subsequent phases • Final design phase (TCP's, etc.) • Construction phase(flaggers)
			9A-DC	➢ Increased number of commercial trucks on existing routes or alternate routes	➢ VEHICLE CHARACTERISTICS	➢ Out of distant payment (pay carriers to stay off routes)

STAGE 4-C: RISK MANAGEMENT CHECKLIST – FINAL DESIGN PHASE

PLANNING & PROGRAMMING	PRELIMINARY DESIGN	FINAL DESIGN	LETTING & AWARD	CONSTRUCTION

	What are the planning activities associated with each project phase?	Who should be part of the risk management team for each project phase? (Stakeholders)		What are the potential hazards associated with each planning activity? (check list)		What are some mitigation strategies for these hazards?
Major Activities:	**Activity Considerations**	**Stakeholders**		**Potential Hazards**	**FACTORS**	**Mitigation Strategies**
Final Design	➢ Final Design • Pavement and bridge design • Traffic control plans • Utility drawings • Hydraulic studies/drainage design ➢ Establish final ROW need ➢ ROW acquisition ➢ Calculation of bid quantities ➢ Cost estimates ➢ Special provisions ➢ Reviews Traffic Control: ➢ Sequence of construction • Work zone speed • Temporary illumination • Preliminary staging plan • Buffer distances ➢ Detour /road closure plan • Temporary pavement • Improvements to alternate routes • Traffic control layout • Merge point details • Intersections (line of sight) • Signs and pavement marking • Pedestrians and Bike plans ➢ Contract Provisions • Accelerated construction • Restrictions (workhour,	➢ Owner/owner agent ➢ Architect/Engineer ➢ Estimators ➢ Contractors and construction managers ➢ Product representatives ➢ Law enforcement ➢ Consultants ➢ Design consultants coordination	0C-C	➢ Driver confusion • Too many decisions (especially at higher speeds) • Driver/operator unfamiliarity • Inadequate/confusing traffic control	➢ WORKZONE CONDITION	➢ Traffic control plan (standards modified to situation) ➢ ➢ Maintain Positive Control - Signage (get signs made up ahead of time) • detour • temporary barrier rails (channelizing) • minimize posted signage (less is more) • use CMS, but minimally before entering area • flashing arrows ➢ Education/Information for unfamiliar drivers ➢ Media (radio/TV), website, advanced warning signs) ➢ Visualization in 3D (information prior to driving in work zones) used in Council Bluffs ➢ Manage Risk During Construction Phase
			1C-C	➢ Multiple Prime in general proximity • Discontinuous workzone signage • Discontinuous traffic control	➢ WORKZONE CONDITION	➢ Contracting and Project Management - Continuity of Traffic Control
			2C-C	➢ Road Characteristics through workzone • Roadway classifications • Narrow bridges • Narrower shoulders • Intersections • Fore slopes • Blind spots • Line of sight obstructions • Limited visibility due to topography	➢ ROAD CHARACTERISTICS	➢ Re-design – modify standard design when appropriate ➢ Standards ➢ Adjustments to standard documents ➢ Engineering & design (widen, remove, modify) ➢ Traffic control devices ➢ Inform Motorist (signs, media, etc.) ➢ Staging (TRAFFIC STAGING???) ➢ Manage Risk During Construction Phase
			3C-LC	➢ Traffic Speed & Speeding • excess traffic speed • limited stopping distance	➢ DRIVER CHARACTERISTICS	➢ Temporary signals ➢ Project Specified Design Speed (advisory speed) – written in specs ➢ Lane narrowing & barriers (design) ➢ Speed cameras (written in specs) ➢ Enforcement details in specifications ➢ Policy enforcement ➢ Manage Risk During Subsequent Phases • Letting • construction

	What are the planning activities associated with each project phase?	Who should be part of the risk management team for each project phase? (Stakeholders)		What are the potential hazards associated with each planning activity? (check list)		What are some mitigation strategies for these hazards?
Major Activities:	Activity Considerations	Stakeholders		Potential Hazards	FACTORS	Mitigation Strategies
	access, lane closures) • Safety		4C-LC	➢ Lack of flexibility in traffic control (lack of incentive for change to traffic control)	➢ WORKZONE CONDITION	➢ Bid Items for traffic control adjustments ➢ Assign bid items for traffic control ➢ Assign responsibility – bid items ➢ Manage Risk during Subsequent Phases • Letting • construction Traffic Control Plans 90% standard 10% Project Specific Goals
			5C-LC	➢ Inadequate capacity/geometry & Confusing layout (increased demand on alternate routes; increased demand on alternate routes) • Detours • Road Closures • Lane Closures o Moving (markings, shoulder repair) o Stationary	➢ WORKZONE CONDITION	➢ Upgrade conditions/geometry ➢ Traffic control plans (signs, barriers, etc) ➢ Manage Risk during construction phase • Media outlets/education/information/closure dates
			7C-C	➢ Inadequate buffer distance	➢ WORKZONE CONDITION	➢ Design adequate buffer space ➢ Manage Risk During Construction Phase
			7C-C	➢ Poor visibility of workers	➢ WORKZONE CONDITION	➢ Bid Items for worker safety training ➢ Project Specification for high visibility worker apparel
			➢	➢ Construction vehicle traffic	➢ WORKZONE CONDITION	➢ Develop schematic Internal Traffic Control Plans (early contractor involvement) ➢ Specify Ingress/egress points ➢ Manage Risk During Construction Phase
			➢	➢ Jobsite Congestion & traffic • Traffic congestion (local traffic) • Traffic delays	➢ WORKZONE CONDITION	➢ Constructability Reviews and Sequencing for concept of work (reverse schedule construction) ➢ Schedule and allowance incentives & workday constraints
			➢		➢	➢
			9C-C	➢ Lack of positive control of traffic	➢ WORKZONE CONDITION	➢ Contracting language & constraints (training, flaggers, barricades, signs/signals, traffic control, etc.) ➢ Manage During Construction Phase
			10C-C	➢ Lack of Visibility/glare/lighting	➢ OPERATING ENVIRONMENT	➢ Specify/Design Glare Screen ➢ Specify/Design Lighting ➢ Specify/design reflectors ➢ Manage During Construction Phase
			11C-C	➢ Driver / Operator Inattention	➢ DRIVER CHARACTERISTICS	➢ Design/specify rumble strips ➢ Taper Designs follow up-to-date MUTCD (reflective) ➢ Specify high visibility worker apparel ➢ Specify CB Radio message in vicinity of transition

	What are the planning activities associated with each project phase?	Who should be part of the risk management team for each project phase? (Stakeholders)		What are the potential hazards associated with each planning activity? (check list)		What are some mitigation strategies for these hazards?
Major Activities:	**Activity Considerations**	**Stakeholders**		**Potential Hazards**	**FACTORS**	**Mitigation Strategies**
						area ➤ Manage Risk During Construction Phase
			12C	➤ Poor Driver Skills	➤ DRIVER CHARACTERISTICS	➤ Education/training/testing ➤ Initiate smart workzone initiatives at letting
			13C	➤ Previous Paint lines (Confusion)	➤ WORKZONE CONDITION	Specify effective removal techniques (sandblasting is preferred but causes other environmental issues)
				➤ Inclement weather	➤ OPERATING ENVIRONMENT	➤ Awareness initiatives, speed control, driver training ➤ Reflectorized barriers, rails, etc. ➤ High visibility worker apparel
				➤ Non-Standard Detour route	➤	ADJUST STANDARDS IF NECESSARY TO FIT ACTUAL SITUATION
			1A-DC	➤ Build/Rebuild under traffic	➤ WORKZONE CONDITION	➤ Determine construction phasing for demo work,etc. ➤ Control Risk during subsequent phases • Construction phase
			2A-DC	➤ Falling Debris/material • Overhead structures repair/replacement • Blasting	➤ WORKZONE CONDITION	➤ Construction Phasing ➤ Construction Schedule ➤ Traffic Control Plans ➤ Control Risk during subsequent phases • Construction phase (contractor mitigation)
			(3A-DC) 6C-LC	➤ Extra Traffic Volume through workzone • Construction traffic • Events • Holidays • Seasonal traffic/road use	➤ OPERATING ENVIRONMENT	➤ Design phase (alignment, geometry, etc.) ➤ Final Design (schedule, standard specs, etc.) ➤ Planning Calendar as part of Bid Documents • Special events • Harvest season completions • Visualization in 3D ➤ Manage/Control Risk during subsequent phases • Letting & Award phase (construction schedule) • Construction phase (Construction Scheduling)
			4A-DC	➤ Detour/Head-to-Head shift/Shoulder Shift • Condition of roadway • Extra traffic volume	➤ ROAD CHARACTERISTICS • Road condition • Road geometry • Road type	➤ Upgrade route prior to letting (if possible) ➤ Re-design road geometry/condition ➤ Control Risk during subsequent phases • Construction phase (flaggers, pace vehicles, law enforcement)
			5A-D C	➤ Posted Speed Through WorkZone	➤ WORKZONE CONDITION	➤ Traffic Control Plans and designs to reduce speed ➤ Control Risk during subsequent phases • Construction phase

	What are the planning activities associated with each project phase?	Who should be part of the risk management team for each project phase? (Stakeholders)		What are the potential hazards associated with each planning activity? (check list)		What are some mitigation strategies for these hazards?
Major Activities:	**Activity Considerations**	**Stakeholders**		**Potential Hazards**	**FACTORS**	**Mitigation Strategies**
			6A-DC	➢ Points of Merge	➢ WORKZONE CONDITION	➢ Design points of merge for traffic & construction requirements ➢ Control Risk during subsequent phases • Construction phase
			7A-DC	➢ Accelerated project completion • Overexposure of workers • Inclement weather construction • External construction completion date requirement (harvest, overlay cure, etc.)	WORKZONE CONDITION OPERATING ENVIRONMENT	➢ Awareness initiatives, speed control, driver training ➢ Reflectorized barriers, rails, etc. ➢ High visibility worker apparel ➢ Control Risk during subsequent phases • Construction phase
			8A-D C	➢ Railroads, Pedestrian Paths & Trail Crossings	➢ OPERATING ENVIRONMENT	➢ Local Jurisdiction agreement and 3rd Party (railroad, etc.) ➢ Design for Pedestrian protection (no standards yet – assign to contractors) ➢ Integrate into the Design of Traffic Control Plans, etc. ➢ Integration with Third Parties • ITS – Integrating Strategies (Intelligent Transportation Systems) ➢ Control Risk during subsequent phases • Construction phase(flaggers)
			9A-DC	➢ Increased number of commercial vehicles (trucks) on existing routes	➢ VEHICLE CHARACTERISTICS	➢ Out of distant payment (pay carriers to stay off routes)
					➢	•
				➢	➢	➢
				➢	➢	➢

STAGE 4-D: RISK MANAGEMENT CHECKLIST – LETTING AND AWARD PHASE

PLANNING & PROGRAMMING	PRELIMINARY DESIGN	FINAL DESIGN	LETTING & AWARD	CONSTRUCTION

	What are the planning activities associated with each project phase?	Who should be part of the risk management team for each project phase? (Stakeholders)		What are the potential hazards associated with each planning activity? (check list)		What are some mitigation strategies for these hazards?
Major Activities:	**Activity Considerations**	**Stakeholders**		**Potential Hazards**	**Contributing Hazards**	**Mitigation Strategies**

LETTING & AWARD
 	
(Procurement)
	Commonly known as the procurement stage:
	• Owner makes the proposed construction documents available to prospective contractors
	• Project Information
	  • Distribution of info
	  • Control of info
	• Contractor qualifications
	  • Experience
	  • Special training and certifications
	• Contractor determines price
	  • Visit site
	  • Assemble price
	  • Calculate
	  • Present
	• Competitive Bidding
	• Contract Negotiations
		➢ Owner/owner agent
		➢ Architect/Engineer
		➢ Prospective Contractors
		➢ Prospective subcontractors
			1D	➢ Missing information (documentation of risk assessment)
				➢ Incomplete plans (TCP's)
				➢ Incomplete bid requirements (safety, etc.)
					➢	➢ Bid item identification
						➢ Pre-bid meetings & communications

			2D	➢ Inadequate Contractor safety training ➢	➢	➢ Contractor Management addressing safety ➢ Minimum site visits by safety director

			3D	➢ Contractor Complacency
				➢
					➢	➢ Contractor fines and sanctions
						  • (lack of PM)
						  • Fines for traffic control

			4D	➢ Workzone area laid out long before construction begins	➢	➢ Contract period is set to reflect actual construction (this prevents contractors from setting out workzone to satisfy contract but waits for construction to start)
			5D	➢ Lack of contractor project management (directed toward safety)	➢	

			6D	➢ Contractor selection	➢	➢ Worker training requirements
						➢ Contractor prequalification using safety record
						  • Evaluation on past project
						  • Insurance rate factor

			7D	➢ Final Schedule not part of contract (project duration)	➢	➢ Schedule and sequencing as condition of contract (meetings & requirements)
			8D	➢ Lack of accident/near-miss reporting structure	➢	➢ Bid item for on-site traffic technician ➢ Bid Item for On-site surveillance
			9D	➢ Non-credible/non-current signs during interim season	➢	➢ Interim phase coordination- season to season signage during project transitions

			1C-LC	➢ Multiple Prime in general proximity
				  • Discontinuous workzone signage
				  • Discontinuous traffic control
					➢	➢ Packaging of lettings to ensure continuity of workzone signage and project management responsibility

			3C-LC	➢ Traffic Speed & Speeding
				  • excess traffic speed
				  • limited stopping distance
					➢ DRIVER CHARACTERISTICS	➢ Policy enforcement
						➢ Manage Risk During Subsequent Phases
						  • construction

			4C-LC	➢ Lack of flexibility in traffic control (lack of incentive for change to traffic control)	➢ WORKZONE CONDITION	➢ Bid Items for traffic control adjustments ➢ Assign bid items for traffic control ➢ Assign responsibility – bid items ➢ Manage Risk during Subsequent Phases • construction

STAGE 4-D: RISK MANAGEMENT CHECKLIST – LETTING AND AWARD PHASE

PLANNING & PROGRAMMING	PRELIMINARY DESIGN	FINAL DESIGN	LETTING & AWARD	CONSTRUCTION

	What are the planning activities associated with each project phase?	Who should be part of the risk management team for each project phase? (Stakeholders)		What are the potential hazards associated with each planning activity? (check list)		What are some mitigation strategies for these hazards?
Major Activities:	**Activity Considerations**	**Stakeholders**		**Potential Hazards**	**Contributing Hazards**	**Mitigation Strategies**
			3A-DLC	➢ Extra traffic volume • Construction traffic • Events • Holidays • Seasonal traffic/road use	➢ OPERATING ENVIRONMENT	➢ Pre-bid meeting to discuss construction schedule ➢ Control Risk during subsequent phases • Construction phase (Construction Scheduling)
			12C	➢ Poor Driver Skills	➢ DRIVER CHARACTERISTICS	➢ Education/training/testing ➢ Initiate smart workzone initiatives at letting
			6C-LC (4A-DC)	➢ Extra Traffic Volume	➢ OPERATING ENVIRONMENT	➢ Contractor Schedule to consider Planning Calendar (special events, harvest season, etc) • Minimize construction operations • No major activities • Minimize excess traffic ➢ Manage Risk during subsequent phases (construction)
			➢		➢	➢
			➢		➢	➢

STAGE 4-E: RISK MANAGEMENT CHECKLIST – CONSTRUCTION PHASE

PLANNING & PROGRAMMING	PRELIMINARY DESIGN	FINAL DESIGN	LETTING & AWARD	CONSTRUCTION

CONSTRUCTION	What are the planning activities associated with each project phase?	Who should be part of the risk management team for each project phase? (Stakeholders)		What are the potential hazards associated with each planning activity? (check list)		What are some mitigation strategies for these hazards?
Major Activities:	**Activity Considerations**	**Stakeholders**		**Potential Hazards**	**FACTORS**	**Mitigation Strategies**
Execution of work required by contract documents	Team effort working toward delivering completed facility ready for its intended use: • Contractor's activities • Planning • Scheduling • Mobilization (Equip) • Material purchasing • Fabrication of components • construction • Construction Categories • Contract Administration • Contractor Project Management • Contractor responsibility • Supervision • Implement/enforce safety rules • Schedule and coordinate deliveries and work • Provided submittals • Communication • Meetings • Project Closeout	➢ Owner/owner agent ➢ Architect/Engineer ➢ Consultants ➢ Testing agencies ➢ Contractors ➢ Subcontractors ➢ Authorities having Jurisdiction (AHJ's) ➢ Product representatives	➢	➢ Inadequate Internal Traffic Control Plans (ITCPs)	➢	➢ Develop ITCP specifically for the anticipated traffic and operating procedures
				➢ High Risk traffic • Friday • Evenings – (bar time) • Rush Hour Traffic	➢	➢ Event Calendar Updates (District) ➢ Coordination meetings ➢ Law Enforcement
			➢	➢ Jobsite Congestion & traffic • Traffic congestion (local traffic) • Traffic delays	➢ WORKZONE CONDITION	➢ Implement sSequencing for concept of work ➢ Schedule and allowance incentives & workday constraints ➢ Permitting for overweight (less truck traffic with larger loads)- annual permits for truckers (to reduce # trucks in workzone) ➢ Ground guides (on site) to prevent motorists from entering worksite ➢ Use of ground guides to manage on site construction traffic (particularly large trucks)
			➢	➢ Non-credible signs	➢	➢ Remove non-credible signs (follow up with enforcement) ➢ Signage and traffic control reviews (credibility)
			➢	➢ Length of workzone (too long)	➢	➢ Lane Rental Specs
			➢	➢ Dirty / non-serviceable signs/reflectors, etc.	➢	➢ Clean & Maintain signs, reflectors, etc. (sign maintenance and safety compliance)
			➢	➢	➢	➢
			0C-LC	➢ Driver confusion • Too many decisions (especially at higher speeds) • Driver/operator unfamiliarity • Inadequate/confusing traffic control	➢ WORKZONE CONDITION	➢ Early warning (multiple simultaneous methods) place in sufficient distance ahead of decision area ➢ CMS ➢ Flashing arrow ➢ Taper (updated MUTCD) ➢ Increase use of reflectorized arrow, signs, painting, etc. ➢ Information OUTLETS • Resident Engineer office • 511 (cell phones) • IA.org (internet) ➢ Media outlet for project information • Lane Closures • Traffic information • Alternate routes • Detours
			1C-C	➢ Multiple Prime in general proximity • Discontinuous workzone signage • Discontinuous traffic control	➢ WORKZONE CONDITION	➢ Contracting and Project Management responsibility ➢ Continuity of Traffic Control devices & signs

CONSTRUCTION	What are the planning activities associated with each project phase?	Who should be part of the risk management team for each project phase? (Stakeholders)		What are the potential hazards associated with each planning activity? (check list)		What are some mitigation strategies for these hazards?
Major Activities:	**Activity Considerations**	**Stakeholders**		**Potential Hazards**	**FACTORS**	**Mitigation Strategies**
			2C-C	➢ Road Characteristics through workzone • Roadway classifications • Narrow bridges • Narrower shoulders • Intersections • Fore slopes • Blind spots • Line of sight obstructions • Limited visibility due to topography	➢ ROAD CHARACTERISTICS	➢ Inform Motorist (signs, etc.) ➢ Employ Traffic control devices ➢ Erect Signs ➢ Staging (TRAFFIC STAGING???) ➢ Field modify when appropriate (with approval) ➢ Manage Risk During Construction Phase
			3C-LC	➢ Traffic Speed & Speeding • excess traffic speed • limited stopping distance	➢ DRIVER CHARACTERISTICS	➢ Temporary signals ➢ Project Specified Design Speed ➢ Lane narrowing ➢ Speed cameras ➢ Law Enforcement posted at critical timeframes (may cause other problems)
			4C-LC	➢ Lack of flexibility in traffic control (lack of incentive for change to traffic control)	➢ WORKZONE CONDITION	➢ Bid Items for traffic control adjustments ➢ Assign bid items for traffic control ➢ Assign responsibility – bid items
			5C-LC	➢ Inadequate capacity/geometry & Confusing layout (increased demand on alternate routes; increased demand on alternate routes) • Detours • Road Closures • Lane Closures o Moving (markings, shoulder repair) o Stationary	➢ WORKZONE CONDITION	➢ Field Upgrade conditions/geometry ➢ Employ Traffic control plans (signs, barriers, etc) ➢ Media outlets • Education • Information • closure dates
				•	➢	➢
			7C-C	➢ Inadequate buffer distance	➢ WORKZONE CONDITION	➢ Maintain / ensure adequate buffer space ➢ Worker training ➢ Slow traffic (positive control)-law enforcement ➢ barriers
			7C-C	➢ Poor visibility of workers	➢ WORKZONE CONDITION	➢ Bid Items for worker safety training ➢ Project Specification for high visibility worker apparel
			➢	➢ Construction vehicle routes	➢ WORKZONE CONDITION	➢ Implement Internal Construction Traffic Control Plans ➢ Employ & Enforce Ingress/egress points
			9C-C	➢ Lack of positive control of traffic	➢ WORKZONE CONDITION	➢ training ➢ flaggers ➢ barricades ➢ signs/signals ➢ traffic control
			10C-C	➢ Lack of Visibility/glare/lighting	➢ OPERATING ENVIRONMENT	➢ workzone smart initiative ➢ Driver training/testing, etc.

CONSTRUCTION	What are the planning activities associated with each project phase?	Who should be part of the risk management team for each project phase? (Stakeholders)		What are the potential hazards associated with each planning activity? (check list)		What are some mitigation strategies for these hazards?
Major Activities:	**Activity Considerations**	**Stakeholders**		**Potential Hazards**	**FACTORS**	**Mitigation Strategies**
						➢ Install Glare Screen ➢ Install Barriers ➢ Install Lighting ➢ Temporary lighting ➢ Lighting placement - Ensure proper placement of portable light units to prevent blinding and glare for motorists
			11C-C	➢ Driver/operator inattention	➢	➢ Taper designs follow up-to-date MUTCD (reflective) ➢ Ensure high visibility worker apparel ➢ Portable rumble strips ➢ Announcement on CB radios in transition area
			12C	➢ Poor Driver Skills • Speed • Stopping distance • Inclement weather	➢ DRIVER CHARACTERISTICS	➢ Education/training/testing ➢ Initiate smart workzone initiatives at letting ➢ Driver training, driver information, awareness initiatives
			13C	➢ Previous Paint lines (Confusion)	➢ WORKZONE CONDITION	➢ Remove previous paint lines (sandblast works best but has environmental consequences)
			1A-DC	➢ Build/Rebuild under traffic	➢ WORKZONE CONDITION	➢ Control Risk during subsequent phases • Design phase (construction phasing for demo work,etc.) • Construction phase
			2A-DC	➢ Falling Debris/material • Overhead structures repair/replacement • Blasting	➢ WORKZONE CONDITION	➢ Construction scheduling
			3A-DC 6C-LC	➢ Extra Traffic Volume through workzone • Construction traffic • Events • Holidays • Seasonal traffic/road use	➢ OPERATING ENVIRONMENT	➢ Restricted construction activities based on Planning Calendar as part of Bid Documents • Special events • Harvest season completions • Event calendar (district) • Coordination meetings ➢ Visualization in 3D ➢ Construction Scheduling
			4A-DC	➢ Detour/Head-to-Head shift/Shoulder Shift • Condition of roadway • Extra traffic volume	➢ ROAD CHARACTERISTICS • Road condition • Road geometry • Road type	➢ flaggers ➢ pace vehicles ➢ law enforcement
			5A-D C	➢ Posted Speed Through WorkZone	➢ WORKZONE CONDITION	➢ law enforcement
			6A-DC	➢ Points of Merge	➢ WORKZONE CONDITION	➢ Monitor and adjust as required(flexibility provided in contract documents)
			7A-DC	➢ Accelerated project completion • Overexposure of workers • Inclement weather construction • External construction completion date requirement (harvest, overlay cure, etc.)	WORKZONE CONDITION OPERATING ENVIRONMENT	➢ Taper designs follow up-to-date MUTCD (reflective) ➢ Ensure high visibility worker apparel ➢ Portable rumble strips ➢ education/training/testing ➢ Initiate smart workzone initiatives at letting ➢ Driver training, driver information, awareness initiatives

CONSTRUCTION	What are the planning activities associated with each project phase?	Who should be part of the risk management team for each project phase? (Stakeholders)		What are the potential hazards associated with each planning activity? (check list)		What are some mitigation strategies for these hazards?
Major Activities:	**Activity Considerations**	**Stakeholders**		**Potential Hazards**	**FACTORS**	**Mitigation Strategies**
			8A-D C	➢ Railroads, Pedestrian Paths & Trail Crossings	➢ OPERATING ENVIRONMENT	➢ Integration with Third Parties ➢ ITS – Monitoring ITS Effectiveness (deployment monitoring) ➢ flaggers
			9A-DC	➢ Increased number of commercial trucks on existing routes or alternate routes	➢ VEHICLE CHARACTERISTICS	➢ Out of distant payment (pay carriers to stay off routes)

APPENDIX D. SURVEY EMAIL LETTER

Transportation industry colleagues;

The Midwest Transportation Consortium, the Center for Transportation Research and Education, and Iowa State University are undertaking an important study of risk in construction work zones on transportation projects. As part of this study, we are conducting a survey of experienced industry professionals to assist us in the development of an integrated risk management model that can be utilized by project managers and administrators with the goal of mitigating work zone crashes and fatalities.

In this survey you will be asked to identify hazards that could contribute to the risk of vehicle crashes and fatalities in work zones from the perspective of a stakeholder with experience in one of the following phases of a typical highway project development process:

1. Planning & Programming - (approx. 10 minutes)
2. Design - (approx. 12 minutes)
3. Letting & Award (bidding) - (approx. 10 minutes)
4. Construction (approx. 15 minutes)

We ask your assistance in completing that portion of the survey which corresponds to the project phase in which you have primary expertise. You will be directed to the appropriate portion of the survey after answering question #2.

Please click on the following link to access the survey through Zoomerang®:

http://www.zoomerang.com/Survey/?p=WEB2293VG2MNZZ

The questions are set up in pairs; therefore, if you do not understand the odd number questions, the following even number question provides information that may clarify the previous question.

Completion of this survey is voluntary and your answers will remain confidential and anonymous. If you have any questions please do not hesitate to contact Dan by email at enz@iastate.edu or Jennifer at jsshane@iastate.edu or 515.294.1703.

Your participation is greatly appreciated. Please complete his survey by May 1, 2009.

Thank you for your time!
Kind Regards,

Dan Enz, PE
Jennifer Shane, PhD
Kelly Strong, PhD

APPENDIX E. INTERNET SURVEY INSTRUMENT

Roadway Workzone Hazards and Mitigation Strategies

Questions marked with an asterisk (*) are mandatory.

WELCOME

This is a survey sponsored by the Midwest Transportation Consortium, the Center for Transportation Research and Education, and Iowa State University. The purpose of this survey, is to support research that will lead to the development of an integrated risk management model that will be utilized by construction project managers and administrators with the goal of mitigating workzone crashes and fatalities.

In this survey you will be asked to identify hazards that could contribute to the risk of vehicle crashes and fatalities in workzones from the perspective of a stakeholder in each phase of a typical roadway project.

In addition, you will be asked to provide mitigation strategies that may be applied to the identified hazard during each phase of the project.

PROJECT DEVELOPMENT PROCESS

For this survey the following are typical activities associated with each project phase (Source: Anderson and Blasche 2004):

Planning & Programming: Purpose and need; improvement or requirement studies; environmental considerations; public involvement/participation; interagency conditions; environmental analysis; schematic development; public hearings; right of way impact; project economic feasibility and funding authorization

Design (Preliminary and Final): Right of way development; environmental clearance; design criteria and parameters; surveys/utility locations; drainage; preliminary plans; geometric alignments; bridge layouts; right of way acquisitions; PS&E development - final pavement and bridge design, traffic control plans, utility drawings, hydraulics studies/drainage design, final cost estimates.

Letting & Award: Prepare contract documents, advertise for bid, pre-bid conference; receive and analyze bids, determine lowest responsive bidder, initiate contract.

Construction: Mobilization; inspection and materials testing; contract administration; traffic control, bridge, pavement, drainage construction.

---

1 What is your employment organization?

- Government (all levels)
- Contractor
- Consultant
- Other, please specify (limit 50 characters w/ spaces)

---

2 * Please check the project phase with which you are most familiar in your role on roadway design and construction teams:

- Planning & Programming
- Design (preliminary & final)
- Letting and Award (Bidding)
- Construction

By clicking on the submit button below, you will be directed to that portion of the survey corresponding to the project phase you selected in question #2.

SUBMIT

Roadway Workzone Hazards and Mitigation Strategies

Questions marked with an asterisk (*) are mandatory.

WELCOME TO THE PLANNING & PROGRAMMING PHASE

In this section you will be asked to identify hazards that could contribute to the risk of vehicle crashes and fatalities in workzones from the perspective of a stakeholder in the planning and programming phase of a typical highway project development process.

Hazards: a circumstance that increases either the frequency or severity of losses

Project Scope:

The intent of this survey is to gather information regardless of size or complexity of the project. However, in many cases, complex bridge and road construction projects provide more information. Therefore, for this survey, assume the questions are referring to large, more complex projects.

Any information you provide, regardless of size and complexity of project, is beneficial to this research, so please answer each question regardless of your prior project experience.

INSTRUCTIONS:

#1) For the odd-number questions, please indicate whether you disagree or agree with the statements by marking the appropriate circle. If you check "disagree", please skip to the next odd-number question.

#2) If you answer "agree" for any of the odd-numbered questions, please proceed to the next even numbered question to check all of the risk mitigation strategies that you believe would be affective for the hazards identified in this project phase. In addition, use the text box to add mitigating strategies that may also be applied during this project phase.

3 During the planning & programming phase, project personnel should identify **"building/rebuilding under traffic"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

4 What are the mitigation strategies for **"building/rebuilding under traffic"** that could be considered during this project phase? (check all that you agree with)

- Detours
- Road Closures
- Lane Closures
- Accept risk and manage/control during subsequent phases (i.e., design phase (construction phasing for demo work,etc.); and construction phase)
- Other, please specify (limit 50 characters w/ spaces)

5 During the planning & programming phase, project personnel should identify **"falling debris/material from: overhead structures & blasting"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

	1 disagree	2 agree
overhead structures	1	2
blasting	1	2

6 What are the mitigation strategies for **"falling debris/material from: overhead structures & blasting"** that could be considered during this project phase? (check all that you agree with)

- Detours
- Road Closures
- Lane Closures
- Accept risk and manage/control during subsequent phases (i.e., design phase (construction phasing for demo work,etc.); and construction phase)
- Other, please specify (limit 50 characters w/ spaces)

7 During the planning & programming phase, project personnel should identify **"traffic congestion & delay through the workzone"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

8 What are the mitigation strategies for **"traffic congestion & delay through the workzone"** that could be considered during this project phase? (check all that you agree with)

- Detours (& alternate routes - on and off site)
- Road Closures
- Lane Closures
- Shoulder Shift
- Accelerated Project Completion Scheduling (to limit exposure of traveling public)
- Other, please specify (limit 50 characters w/ spaces)

9 During the planning & programming phase, project personnel should identify **"extra traffic volume through the workzone from: construction traffic; civic events; holidays; and seasonal traffic/road use"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

	1 disagree	2 agree
construction traffic	1	2
civic events	1	2
holidays	1	2
seasonal traffic/road use	1	2

10 What are the mitigation strategies for **"extra traffic volume through the workzone from: construction traffic; civic events; holidays; and seasonal traffic/road use"** that could be considered during this project phase? (check all that you agree with)

- Accept risk and manage/control during subsequent phases
- Other, please specify (limit 50 characters w/spaces)

11 During the planning & programming phase, project personnel should identify **"the condition of roadway & extra traffic volume of: detours; head-to-head traffic shifts; and shoulder shifts"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

12 What are the mitigation strategies for **"the condition of roadway & extra traffic volume of: detours; head-to-head traffic shifts; and shoulder shifts"** that could be considered during this project phase? (check all that you agree with)

- Recon/drive detour to identify potential problems
- Upgrade route prior to letting (if possible)
- Accept risk and manage/control during subsequent phases (·Design phase (road geometry/condition) · Construction phase (flaggers, pilot cars, law enforcement))
- Other, please specify (limit 50 characters w/spaces)

13 During the planning & programming phase, project personnel should identify **"the posted speed through the workzone"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

14 What are the mitigation strategies for **"the posted speed through the workzone"** that could be considered during this project phase? (check all that you agree with)

- Policy Change
- Accept risk and manage/control during subsequent phases (·Design phase · Construction phase)
- Other, please specify (limit 50 characters w/spaces)

15 During the planning & programming phase, project personnel should identify **"the points of merge"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

16 What are the mitigation strategies for **"the points of merge"** that could be considered during this project phase? (check all that you agree with)

- Accept risk and manage/control during subsequent phases (·Design phase · Construction phase)
- Other, please specify (limit 50 characters w/spaces)

17 During the planning & programming phase, project personnel should identify **"accelerated project completion requirements (i.e., overexposure of workers; inclement weather construction; external construction completion date requirement -harvest, overlay cure time, etc.)"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

	1 disagree	2 agree
overexposure of workers	1	2
inclement weather construction	1	2
external construction completion date requirement	1	2

18 What are the mitigation strategies for **"accelerated project completion requirements (i.e., overexposure of workers; inclement weather construction; external construction completion date requirement -harvest, overlay cure time, etc.)"** that could be considered during this project phase? (check all that you agree with)

- Select materials that may minimize construction duration (·PCC vs.ACC;·Full Depth vs. Overlay)
- Use innovative contracting methods (A+B, I/D Clauses, lane rental specifications)
- Early letting to allow for early procurement to meet long lead times
- Accept risk and manage/control during subsequent phases (i.e., design phase and construction phase)
- Other, please specify (limit 50 characters w/spaces)

19 During the planning & programming phase, project personnel should identify **"railroads, pedestrian paths/travel routes & trail crossings"** as hazards that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

20 What are the mitigation strategies for **"railroads, pedestrian paths/travel routes & trail crossings"** that could be considered during this project phase? (check all that you agree with)

- Integration with Third Parties (coordination & ITS – Integrating Strategies (Intelligent Transportation Systems))
- Accept risk and manage/control during subsequent phases (·Design phase (TCP's, etc) · Construction phase (flaggers))
- Other, please specify (limit 50 characters w/spaces)

21 During the planning & programming phase, project personnel should identify **"increased number of commercial trucks on existing routes or alternate routes"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

22 What are the mitigation strategies for **"increased number of commercial trucks on existing routes or alternate routes"** that could be considered during this project phase? (use text box)

23 During the planning & programming phase, project personnel should identify **the following** as additional hazards that could contribute to the risk of the vehicle crashes and fatalities in workzones:

Also, list any appropriate mitigation strategies.

24 * Thank you for your participation. You may submit your answers by clicking on the "Exit Survey" circle below

Exit Survey

SUBMIT

Roadway Workzone Hazards and Mitigation Strategies

WELCOME TO THE DESIGN PHASE

In this section you will be asked to identify hazards that could contribute to the risk of vehicle crashes and fatalities in workzones from the perspective of a stakeholder in the design phase of a typical highway project development process.

Hazards: a circumstance that increases either the frequency or severity of losses

Project Scope:

The intent of this survey is to gather information regardless of size or complexity of the project. However, in many cases, complex bridge and road construction projects provide more information. Therefore, for this survey, assume the questions are referring to large, more complex projects.

Any information you provide, regardless of size and complexity of project, is beneficial to this research, so please answer each question regardless of your prior project experience.

INSTRUCTIONS:

#1) For the odd-number questions, please indicate whether you disagree or agree with the statements by marking the appropriate circle. If you check "disagree", please skip to the next odd-number question.

#2) If you answer "agree" for any of the odd-numbered questions, please proceed to the next even numbered question to check all of the risk mitigation strategies that you believe would be affective for the hazards identified in this project phase. In addition, use the text box to add mitigating strategies that may also be applied during this project phase.

3 During the design phase, project personnel should identify **"driver confusion from: too many decisions (especially at higher speeds); driver/operator unfamiliarity; and inadequate/confusing traffic control"** as a hazard that could contribute to the risk of vehicle crashes and fatalities in workzones.

disagree	agree
1	2

4 What are the mitigation strategies for **"driver confusion from: too many decisions (especially at higher speeds); driver/operator unfamiliarity; and inadequate/confusing traffic control"** that could be considered during this project phase? (check all that you agree with)

- Design for Positive Traffic Control - Signage (get signs made up ahead of time)
- detour signage
- temporary barrier rails (channelizing)
- minimize posted signage (less is more)
- use CMS (changeable message signs), but minimally before entering work area
- flashing arrows
- Education/Information for unfamiliar drivers
- Media (radio/TV), website, advanced warning signs)
- Visualization in 3D (information prior to driving in work zones) used in Council Bluffs, IA)
- Accept risk and manage/control during subsequent phases
- Other, please specify (limit 50 characters w/spaces)

5 During the design phase, project personnel should identify **"multiple prime in general proximity (resulting in discontinuous workzone signage & discontinuous traffic control)"** as a hazard that could contribute to the risk of vehicle crashes and fatalities in workzones.

disagree	agree
1	2

6 What are the mitigation strategies for **"multiple prime in general proximity (resulting in discontinuous workzone signage & discontinuous traffic control)"** that could be considered during this project phase? (check all that you agree with)

- Specify Contracting and Project Management responsibility
- Specify Continuity of Traffic Control devices & signs
- Accept risk and manage/control during subsequent phases
- Other, please specify (limit 50 characters w/spaces)

7 During the design phase, project personnel should identify **"road characteristics through the workzone (i.e., roadway classifications; narrow bridges; narrower shoulders; intersections; fore slopes; blind spots; line of sight obstructions; limited visibility due to topography)"** as a hazard that could contribute to the risk of vehicle crashes and fatalities in workzones.

disagree	agree
1	2

8 What are the mitigation strategies for **"road characteristics through the workzone (i.e., roadway classifications; narrow bridges; narrower shoulders; intersections; fore slopes; blind spots; line of sight obstructions; limited visibility due to topography)"** that could be considered during this project phase? (check all that you agree with)

- Re-design – modify standard design when appropriate
- Standards
- Adjustments to standard documents
- Engineering & design (widen, remove, modify)
- Traffic control devices
- Inform Motorist (signs, media, etc.)
- Traffic Staging Plans (complex urban areas, etc)
- Accept risk and manage/control during subsequent phases
- Other, please specify (limit 50 characters w/spaces)

9 During the design phase, project personnel should identify **"traffic speed & speeding (i.e., excess traffic speed, and limited stopping distance)"** as a hazard that could contribute to the risk of vehicle crashes and fatalities in workzones.

disagree	agree
1	2

10 What are the mitigation strategies for **"traffic speed & speeding (i.e. excess traffic speed, and limited stopping distance)"** that could be considered during this project phase? (check all that you agree with)

- Temporary signals
- Project Specified Design Speed (advisory speed) – written in specs
- Lane narrowing & barriers (design)
- Speed cameras (written in specs)
- Enforcement details in specifications
- Policy enforcement
- Accept risk and manage/control during subsequent phases (Letting, construction)
- Other, please specify (limit 50 characters w/spaces)

11 During the design phase, project personnel should identify **"lack of contractor innovation in traffic control methods"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

12 What are the mitigation strategies for **"lack of contractor innovation in traffic control methods"** that could be considered during this project phase? (check all that you agree with)

- Bid Items for traffic control adjustments
- Assign bid items for traffic control
- Assign responsibility – bid items
- Accept risk and manage/control during subsequent phases (· Letting; · construction)
- Other, please specify (limit 50 characters w/spaces)

13 During the design phase, project personnel should identify **"increased demand of, inadequate capacity/geometry & confusing layout of: detours; road closures; and lane closures (moving & stationary)"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

14 What are the mitigation strategies for **"increased demand of, inadequate capacity/geometry & confusing layout of: detours; road closures; and lane closures (moving & stationary)"** that could be considered during this project phase? (check all that you agree with)

- Upgrade conditions/geometry
- Traffic control plans (signs, barriers, etc)
- Accept risk and manage/control during subsequent phases (media outlets/education/information/closure dates)
- Other, please specify (limit 50 characters w/spaces)

15 During the design phase, project personnel should identify **"inadequate buffer distance from travel lane to work area"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

16 What are the mitigation strategies for **"inadequate buffer distance from travel lane to work area"** that could be considered during this project phase? (check all that you agree with)

- Design adequate buffer space
- Provide positive protection (barriers)
- Accept risk and manage/control during construction phase
- Other, please specify (limit 50 characters w/spaces)

17 During the design phase, project personnel should identify **"poor visibility of workers"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

18 What are the mitigation strategies for **"poor visibility of workers"** that could be considered during this project phase? (check all that you agree with)

- Project specification for worker safety training
- Project Specification for high visibility worker apparel
- Accept risk and manage/control during subsequent phases
- Other, please specify (limit 50 characters w/spaces)

19 During the design phase, project personnel should identify **"construction vehicle traffic"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

20 What are the mitigation strategies for **"construction vehicle traffic"** that could be considered during this project phase? (check all that you agree with)

- Develop schematic Internal Traffic Control Plans (use early contractor involvement)
- Specify Ingress/egress points
- Accept risk and manage/control during construction phase
- Other, please specify (limit 50 characters w/spaces)

21 During the design phase, project personnel should identify **"jobsite congestion & traffic resulting in local traffic congestion and delays"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

22 What are the mitigation strategies for **"jobsite congestion & traffic resulting in local traffic congestion and delays"** that could be considered during this project phase? (check all that you agree with)

- Ensure constructability reviews and sequencing for concept of work (reverse schedule construction)
- Provide schedule and allowance incentives & workday constraints
- Accept risk and manage/control during construction phase
- Other, please specify (limit 50 characters w/spaces)

23 During the design phase, project personnel should identify **"lack of positive control of traffic"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

24 What are the mitigation strategies for **"lack of positive control of traffic"** that could be considered during this project phase? (check all that you agree with)

- Develop contracting language & constraints (training, flaggers, barricades, signs/signals, traffic control, etc.)
- Provide bid items for use of barriers
- Specify use of ITS (intelligent transportation systems)
- Accept risk and manage/control during construction phase
- Other, please specify (limit 50 characters w/spaces)

25 During the design phase, project personnel should identify **"lack of visibility/glare/lighting"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

26 What are the mitigation strategies for **"lack of visibility/glare/lighting"** that could be considered during this project phase? (check all that you agree with)

- Specify/Design Glare Screen
- Specify/Design Lighting
- Specify/design reflectors
- Accept risk and manage/control during construction phase
- Other, please specify (limit 50 characters w/spaces)

27 During the design phase, project personnel should identify **"driver / operator inattention"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

28 What are the mitigation strategies for **"driver / operator inattention"** that could be considered during this project phase? (check all that you agree with)

- Design/specify rumble strips
- Taper Designs follow up-to-date MUTCD (reflective)
- Specify high visibility worker apparel
- Specify CB Radio message in vicinity of transition area
- Specify use of ITS (intelligent transportation systems)
- Accept risk and manage/control during construction phase
- Other, please specify (limit 50 characters w/spaces)

Please click the "submit" button to continue with the design phase survey.

SUBMIT

Roadway Workzone Hazards and Mitigation Strategies

WELCOME TO THE LETTING & AWARD PHASE

In this section you will be asked to identify hazards that could contribute to the risk of vehicle crashes and fatalities in workzones from the perspective of a stakeholder in the letting & award phase of a typical highway project development process.

Hazards: a circumstance that increases either the frequency or severity of losses

Project Scope:

The intent of this survey is to gather information regardless of size or complexity of the project. However, in many cases, complex bridge and road construction projects provide more information. Therefore, for this survey, assume the questions are referring to large, more complex projects.

Any information you provide, regardless of size and complexity of project, is beneficial to this research, so please answer each question regardless of your prior project experience.

INSTRUCTIONS:

#1) For the odd-number questions, please indicate whether you disagree or agree with the statements by marking the appropriate circle. If you check "disagree", please skip to the next odd-number question.

#2) If you answer "agree" for any of the odd-numbered questions, please proceed to the next even numbered question to check all of the risk mitigation strategies that you believe would be affective for the hazards identified <u>in this project phase</u>. In addition, use the text box to add mitigating strategies that may also be applied during this project phase.

3 During the letting & award phase, project personnel should identify **"missing information (documentation of risk assessment); incomplete plans (TCP's); and incomplete bid requirements"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

4 What are the mitigation strategies for **"missing information (documentation of risk assessment); incomplete plans (TCP's); and incomplete bid requirements"** that could be considered during this project phase? (check all that you agree with)

- Bid item identification
- Preliminary plan review
- Pre-bid meetings & communications
- Other, please specify (limit 50 characters w/spaces)

5 During the letting & award phase, project personnel should identify **"inadequate contractor accountability for safety"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

6 What are the mitigation strategies for **"inadequate contractor accountability for safety"** that could be considered during this project phase? (check all that you agree with)

- Establish contractor management structure addressing safety as a qualification requirement
- Use of contractor evaluations for bid capacity
- Prescribe minimum site visits by safety director
- Other, please specify (limit 50 characters w/spaces)

7 During the letting & award phase, project personnel should identify **"contractor complacency"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

8 What are the mitigation strategies for **"contractor complacency"** that could be considered during this project phase? (check all that you agree with)

- Outline contractor fines and sanctions as contract requirements for: lack of project management; lack of proper traffic control
- Use of contractor evaluations for bid capacity
- Other, please specify (limit 50 characters w/spaces)

9 During the letting & award phase, project personnel should identify **"the workzone area being laid out long before construction actually begins"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

10 What are the mitigation strategies for **"the workzone area being laid out long before construction actually begins"** that could be considered during this project phase? (check all that you agree with)

- Set contract period to reflect actual construction schedule (this prevents contractors from setting out the workzone to satisfy the contract but waits for construction to begin)
- Other, please specify (limit 50 characters w/spaces)

11 During the letting & award phase, project personnel should identify **"lack of contractor project management (directed toward safety)"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

12 What are the mitigation strategies for **"lack of contractor project management (directed toward safety)"** that could be considered during this project phase? (check all that you agree with)

- Prequalify contractors based on expertise of project management team
- Use of contractor evaluations for bid capacity
- Other, please specify (limit 50 characters w/spaces)

13 During the letting & award phase, project personnel should identify **"contractor selection process"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

14 What are the mitigation strategies for **"contractor selection process"** that could be considered during this project phase? (check all that you agree with)

- Prequalify contractor based on worker safety training program
- Prequalify contractor using safety record (Evaluation of past projects, and Insurance rate factors)
- Use of contractor evaluations for bid capacity
- Other, please specify (limit 50 characters w/spaces)

15 During the letting & award phase, project personnel should identify **"a contract that does not include a final schedule showing project duration and event planning"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

16 What are the mitigation strategies for **"a contract that does not include a final schedule showing project duration and event planning"** that could be considered during this project phase? (check all that you agree with)

- Require that the schedule and sequencing are conditions of the contract including: meetings, specific project safety requirements
- Other, please specify (limit 50 characters w/spaces)

17 During the letting & award phase, project personnel should identify **"lack of accident/near-miss reporting structure"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

18 What are the mitigation strategies for **"lack of accident/near-miss reporting structure"** that could be considered during this project phase? (check all that you agree with)

- Bid item for on-site safety technician
- Bid item for on-site surveillance
- Other, please specify (limit 50 characters w/spaces)

Please click the "submit" button to continue with the letting & award phase survey.

SUBMIT

Roadway Workzone Hazards and Mitigation Strategies

Questions marked with an asterisk (*) are mandatory.

19 During the letting & award phase, project personnel should identify **"non-credible/non-current signs during interim season"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

20 What are the mitigation strategies for **"non-credible/non-current signs during interim season"** that could be considered during this project phase? (check all that you agree with)

- Interim phase coordination – season to season signage during project transitions
- Other, please specify (limit 50 characters w/spaces)

21 During the letting & award phase, project personnel should identify **"multiple prime in general proximity (resulting in discontinuous workzone signage & discontinuous traffic control)"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

22 What are the mitigation strategies for **"multiple prime in general proximity (resulting in discontinuous workzone signage & discontinuous traffic control)"** that could be considered during this project phase? (check all that you agree with)

- Packaging of lettings to ensure continuity of workzone signage and project management responsibility
- Other, please specify (limit 50 characters w/spaces)

23 During the letting & award phase, project personnel should identify **"traffic speed & speeding (i.e., excess traffic speed, and limited stopping distance)"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

24 What are the mitigation strategies for **"traffic speed & speeding (i.e., excess traffic speed, and limited stopping distance)"** that could be considered during this project phase? (check all that you agree with)

- Policy for adding extra enforcement
- Legislation (such as fines double in workzones)
- Manage During Construction Phase
- Other, please specify (limit 50 characters w/spaces)

25 During the letting & award phase, project personnel should identify **"lack of contractor innovation in traffic control methods"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

26 What are the mitigation strategies for **"lack of contractor innovation in traffic control methods"** that could be considered during this project phase? (check all that you agree with)

- Bid items for traffic control adjustments
- Assign bid items for traffic control
- Assign project responsibility
- Accept risk and manage/control during construction phase
- Other, please specify (limit 50 characters w/spaces)

---

27 During the letting & award phase, project personnel should identify **"extra traffic volume through the workzone from: construction traffic; civic events; holidays; and seasonal traffic/road use"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

	1 disagree	2 agree
construction traffic	1	2
civic events	1	2
holidays	1	2
seasonal traffic/road use	1	2

---

28 What are the mitigation strategies for **"extra traffic volume through the workzone from: construction traffic; civic events; holidays; and seasonal traffic/road use"** that could be considered during this project phase? (check all that you agree with)

- Conduct pre-bid meeting to discuss construction schedule
- Spell out limitations to the contract such as: minimize construction operations at critical time, obstain from major construction activities, minimize excess traffic
- Accept risk and manage/control during construction phase (scheduling)
- Other, please specify (limit 50 characters w/spaces)

29 During the letting & award phase, project personnel should identify **"poor driver skills"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

30 What are the mitigation strategies for **"poor driver skills"** that could be considered during this project phase? (check all that you agree with)

- Education
- Training
- Testing
- Initiate smart workzone initiatives at letting
- Other, please specify (limit 50 characters w/spaces)

31 During the letting & award phase, project personnel should identify **"high risk traffic (i.e., Fridays, evenings - (bar time), and rush hour traffic)"** as hazards that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

32 What are the mitigation strategies for **"high risk traffic (i.e., Fridays, evenings - (bar time), and rush hour traffic)"** that could be considered during this project phase? (check all that you agree with)

- Review limits to contract (workday restrictions, etc)
- Accept risk and manage/control during subsequent phases
- Other, please specify (limit 50 characters w/spaces)

33 During the letting & award phase, project personnel should identify **the following** as additional hazards that could contribute to the risk of the vehicle crashes and fatalities in workzones:

Also, list any appropriate mitigation strategies.

34 * Thank you for your participation. You may submit your answers by clicking on the "Exit Survey" circle below

- Exit Survey

SUBMIT

Roadway Workzone Hazards and Mitigation Strategies

WELCOME TO THE CONSTRUCTION PHASE

In this section you will be asked to identify hazards that could contribute to the risk of vehicle crashes and fatalities in workzones from the perspective of a stakeholder in the construction phase of a typical highway project development process.

Hazards: a circumstance that increases either the frequency or severity of losses

Project Scope:

The intent of this survey is to gather information regardless of size or complexity of the project. However, in many cases, complex bridge and road construction projects provide more information. Therefore, for this survey, assume the questions are referring to large, more complex projects.

Any information you provide, regardless of size and complexity of project, is beneficial to this research, so please answer each question regardless of your prior project experience.

INSTRUCTIONS:

#1) For the odd-number questions, please indicate whether you disagree or agree with the statements by marking the appropriate circle. If you check "disagree", please skip to the next odd-number question.

#2) If you answer "agree" for any of the odd-numbered questions, please proceed to the next even numbered question to check all of the risk mitigation strategies that you believe would be affective for the hazards identified in this project phase. In addition, use the text box to add mitigating strategies that may also be applied during this project phase.

3 During the construction phase, project personnel should identify **"inadequate internal traffic control plans (ITCPs)"** as a hazard that could contribute to the risk of vehicle crashes and fatalities in workzones.

disagree	agree
1	2

4 What are the mitigation strategies for **"inadequate internal traffic control plans (ITCPs)"** that could be considered during this project phase? (check all that you agree with)

- Develop ITCP specifically for the anticipated traffic and operating procedures
- Other, please specify (limit 50 characters w/spaces)

5 During the construction phase, project personnel should identify **"high risk traffic (i.e., Fridays, evenings (bar time), and rush hour traffic)"** as a hazard that could contribute to the risk of vehicle crashes and fatalities in workzones.

disagree	agree
1	2

6 What are the mitigation strategies for **"high risk traffic (i.e., Fridays, evenings - (bar time), and rush hour traffic)"** that could be considered during this project phase? (check all that you agree with)

- Uphold limitations to contract
- Event Calendar Updates from District
- Coordination meetings
- Law Enforcement
- Other, please specify (limit 50 characters w/spaces)

7 During the construction phase, project personnel should identify **"non-credible/non-current signs during interim season"** as a hazard that could contribute to the risk of vehicle crashes and fatalities in workzones.

disagree	agree
1	2

8 What are the mitigation strategies for **"non-credible/non-current signs during interim season"** that could be considered during this project phase? (check all that you agree with)

- Remove non-credible signs (follow up with enforcement)
- Signage and traffic control reviews (check credibility)
- Other, please specify (limit 50 characters w/spaces)

9 During the construction phase, project personnel should identify **"too long of workzone length"** as a hazard that could contribute to the risk of vehicle crashes and fatalities in workzones.

disagree	agree
1	2

10 What are the mitigation strategies for **"too long of workzone length"** that could be considered during this project phase? (check all that you agree with)

- Lane rental specifications
- Other, please specify (limit 50 characters w/spaces)

11 During the construction phase, project personnel should identify **"dirty/non-serviceable signs/reflectors, etc."** as a hazard that could contribute to the risk of vehicle crashes and fatalities in workzones.

disagree	agree
1	2

12 What are the mitigation strategies for **"dirty/non-serviceable signs/reflectors, etc."** that could be considered during this project phase? (check all that you agree with)

- Clean and maintain signs, reflectors, etc
- Ensure that sign maintenance is part of safety compliance program
- Other, please specify (limit 50 characters w/spaces)

13 During the construction phase, project personnel should identify **"driver confusion from: too many decisions (especially at higher speeds); driver/operator unfamiliarity; and inadequate/confusing traffic control"** as a hazard that could contribute to the risk of vehicle crashes and fatalities in workzones.

disagree	agree
1	2

14 What are the mitigation strategies for **"driver confusion from: too many decisions (especially at higher speeds); driver/operator unfamiliarity; and inadequate/confusing traffic control"** that could be considered during this project phase? (check all that you agree with)

- Employ ITS - early warning (multiple simultaneous methods) place in sufficient distance ahead of decision area
- CMS (changeable message signs)
- Flashing arrow
- Properly Constructed Taper (updated MUTCD)
- Increase use of reflectorized arrow, signs, painting, etc.
- Information outlets: (Resident engineer office; 511 cell phone; internet (IA.org))
- Media outlet for project information (lane closures, traffic information, alternate routes, and detours)
- Other, please specify (limit 50 characters w/spaces)

15 During the construction phase, project personnel should identify **"multiple prime in general proximity (resulting in discontinuous workzone signage & discontinuous traffic control)"** as a hazard that could contribute to the risk of vehicle crashes and fatalities in workzones.

disagree	agree
1	2

16 What are the mitigation strategies for **"multiple prime in general proximity (resulting in discontinuous workzone signage & discontinuous traffic control)"** that could be considered during this project phase? (check all that you agree with)

- Enforce Contracting and Project Management responsibility
- Ensure Continuity of Traffic Control devices & signs
- Other, please specify (limit 50 characters w/spaces)

17 During the construction phase, project personnel should identify **"road characteristics through the workzone (i.e., roadway classifications; narrow bridges; narrower shoulders; intersections; fore slopes; blind spots; line of sight obstructions; limited visibility due to topography)"** as a hazard that could contribute to the risk of vehicle crashes and fatalities in workzones.

disagree	agree
1	2

18 What are the mitigation strategies for **"road characteristics through the workzone (i.e., roadway classifications; narrow bridges; narrower shoulders; intersections; fore slopes; blind spots; line of sight obstructions; limited visibility due to topography)"** that could be considered during this project phase? (check all that you agree with)

- Inform motorist (signs, etc)
- Employ Traffic Control Devices
- Erect signs
- Implement traffic staging plans
- Field modifications (with approval)
- Other, please specify (limit 50 characters w/spaces)

19 During the construction phase, project personnel should identify **"traffic speed & speeding (i.e., excess traffic speed, and limited stopping distance)"** as a hazard that could contribute to the risk of vehicle crashes and fatalities in workzones.

disagree	agree
1	2

20 What are the mitigation strategies for **"traffic speed & speeding (i.e. excess traffic speed, and limited stopping distance)"** that could be considered during this project phase? (check all that you agree with)

- Temporary Signals
- Project Specified design speed
- Lane narrowing
- Speed Cameras
- Law enforcement posted at critical timeframes (may cause other problems)
- Other, please specify (limit 50 characters w/spaces)

21 During the construction phase, project personnel should identify **"lack of contractor innovation in traffic control methods"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

22 What are the mitigation strategies for **"lack of contractor innovation in traffic control methods"** that could be considered during this project phase? (check all that you agree with)

- Bid Items for traffic control adjustments
- Encourage value engineering proposals
- Assign bid items for traffic control
- Assign responsibility – bid items
- Other, please specify (limit 50 characters w/spaces)

23 During the construction phase, project personnel should identify **"increased demand of, inadequate capacity/geometry & confusing layout of: detours; road closures; and lane closures (moving & stationary)"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

24 What are the mitigation strategies for **"increased demand of, inadequate capacity/geometry & confusing layout of: detours; road closures; and lane closures (moving & stationary)"** that could be considered during this project phase? (check all that you agree with)

- Field upgrade conditions/geometry
- Employ traffic control plans (signs, barriers, etc)
- Utilize Media outlets for: (· Education,· Information)
- Monitor and recommend improvements
- Other, please specify (limit 50 characters w/spaces)

25 During the construction phase, project personnel should identify **"inadequate buffer distance from travel lane to work area"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

26 What are the mitigation strategies for **"inadequate buffer distance from travel lane to work area"** that could be considered during this project phase? (check all that you agree with)

- Ensure/maintain adequate buffer space
- Worker safety training
- Reduce traffic speed (positive control & law enforcement)
- Barriers
- Other, please specify (limit 50 characters w/spaces)

27 During the construction phase, project personnel should identify **"poor visibility of workers"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

28 What are the mitigation strategies for **"poor visibility of workers"** that could be considered during this project phase? (check all that you agree with)

- Worker safety training
- Enforce wear of high visibility worker apparel
- Other, please specify (limit 50 characters w/spaces)

29 During the construction phase, project personnel should identify **"construction vehicle traffic"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

30 What are the mitigation strategies for **"construction vehicle traffic"** that could be considered during this project phase? (check all that you agree with)

- Implement and adjust Internal Traffic Control Plans
- Employ & enforce points of ingress/egress
- Other, please specify (limit 50 characters w/spaces)

31 During the construction phase, project personnel should identify **"jobsite congestion & traffic resulting in local traffic congestion and delays"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

32 What are the mitigation strategies for **"jobsite congestion & traffic resulting in local traffic congestion and delays"** that could be considered during this project phase? (check all that you agree with)

- Implement sequencing for the concept of work
- Satisfy schedule and allowance incentives & workday constraints
- Communicate traffic restrictions on DOT website (particularly for oversized loads through workzones)
- Ground guides (on-site) to prevent motorists from entering worksite
- Use of ground guides to manage on-site construction traffic (particularly large trucks)
- Other, please specify (limit 50 characters w/spaces)

Please click the "submit" button to continue with the construction phase survey.

SUBMIT

33 During the construction phase, project personnel should identify **"lack of positive control of traffic"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

34 What are the mitigation strategies for **"lack of positive control of traffic"** that could be considered during this project phase? (check all that you agree with)

- Training
- Flaggers
- Barricades
- Signs/signals
- Law enforcement
- Other, please specify (limit 50 characters w/spaces)

35 During the construction phase, project personnel should identify **"lack of visibility/glare/lighting"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

36 What are the mitigation strategies for **"lack of visibility/glare/lighting"** that could be considered during this project phase? (check all that you agree with)

- Install glare screen
- Install lighting
- Ensure proper placement of portable lighting unit to prevent blinding and glare for motorists
- Other, please specify (limit 50 characters w/spaces)

37 During the construction phase, project personnel should identify **"driver / operator inattention"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

38 What are the mitigation strategies for **"driver / operator inattention"** that could be considered during this project phase? (check all that you agree with)

- Taper designs to follow up-to-date MUTCD (reflective)
- Utilize/employ ITS systems
- Ensure high visibility worker apparel
- Install portable rumble strips
- Announcement on CB radios in transition areas
- Other, please specify (limit 50 characters w/spaces)

39 During the construction phase, project personnel should identify **"poor driver skills"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

40 What are the mitigation strategies for **"poor driver skills"** that could be considered during this project phase? (check all that you agree with)

- Education
- Training
- Testing
- Smart workzone initiatives
- Other, please specify (limit 50 characters w/spaces)

41 During the construction phase, project personnel should identify **"previous paint lines (confusion)"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

42 What are the mitigation strategies for **"previous paint lines (confusion)"** that could be considered during this project phase? (check all that you agree with)

- Remove previous paint lines (sandblasting is preferred but causes other environmental issues)
- Use temporary pavement marking tape in leiu of paint during staging
- Other, please specify (limit 50 characters w/spaces)

43 During the construction phase, project personnel should identify **"inclement weather"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

44 What are the mitigation strategies for **"inclement weather"** that could be considered during this project phase? (check all that you agree with)

- Driver awareness initiatives
- Speed control
- Driver training
- Reflectorized barriers, rails, etc
- High visibility worker apparel
- Other, please specify (limit 50 characters w/spaces)

45 During the construction phase, project personnel should identify **"building/rebuilding under traffic"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

46 What are the mitigation strategies for **"building/rebuilding under traffic"** that could be considered during this project phase? (check all that you agree with)

- Traffic awareness
- Monitor traffic safety issues
- Truck mounted attenuators
- High visibility worker apparel
- Other, please specify (limit 50 characters w/spaces)

47 During the construction phase, project personnel should identify **"falling debris/material from: overhead structures & blasting"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

	1 disagree	2 agree
from overhead structures	1	2
from blasting	1	2

48 What are the mitigation strategies for **"falling debris/material from: overhead structures & blasting"** that could be considered during this project phase? (check all that you agree with)

- Require constractor submittal of protection plan
- Implement construction phasing
- Uphold construction schedule
- Monitor traffic control effectiveness
- Other, please specify (limit 50 characters w/spaces)

49 During the construction phase, project personnel should identify **"extra traffic volume through the workzone from: construction traffic; civic events; holidays; and seasonal traffic/road use"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

	1 disagree	2 agree
construction traffic	1	2
civic events	1	2
holidays	1	2
seasonal traffic/road use	1	2

50 What are the mitigation strategies for **"extra traffic volume through the workzone from: construction traffic; civic events; holidays; and seasonal traffic/road use"** that could be considered during this project phase? (check all that you agree with)

- Coordination meetings
- Construction Scheduling
- Restricted construction activities based on planning calendar (updated by district to include: · Special events, · Harvest season completions)
- 3D Visualization of project schedule provided
- Other, please specify (limit 50 characters w/spaces)

51 During the construction phase, project personnel should identify **"the condition of roadway & extra traffic volume of: detours; head-to-head traffic shifts; and shoulder shifts"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

52 What are the mitigation strategies for **"the condition of roadway & extra traffic volume of: detours; head-to-head traffic shifts; and shoulder shifts"** that could be considered during this project phase? (check all that you agree with)

- Flaggers
- Pilot cars
- Law enforcement
- Other, please specify (limit 50 characters w/spaces)

53 During the construction phase, project personnel should identify **"the posted speed through the workzone"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

54 What are the mitigation strategies for **"the posted speed through the workzone"** that could be considered during this project phase? (check all that you agree with)

- Law enforcement
- Monitor traffic control affectiveness & modify as necessary
- Other, please specify (limit 50 characters w/spaces)

55 During the construction phase, project personnel should identify **"the points of merge"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

56 What are the mitigation strategies for **"the points of merge"** that could be considered during this project phase? (check all that you agree with)

- Monitor and adjust as necessary (flexibility provided in contract documents)
- Utilize / employ ITS
- Other, please specify (limit 50 characters w/spaces)

57 During the construction phase, project personnel should identify **"accelerated project completion requirements (i.e., overexposure of workers; inclement weather construction; external construction completion date requirement -harvest, overlay cure time, etc.)"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

	1 disagree	2 agree
overexposure of workers	1	2
inclement weather construction	1	2
external construction completion date requirement	1	2

58 What are the mitigation strategies for **"accelerated project completion requirements (i.e., overexposure of workers; inclement weather construction; external construction completion date requirement -harvest, overlay cure time, etc.)"** that could be considered during this project phase? (check all that you agree with)

- Awareness initiatives, speed control, driver training
- Reflectorized barriers, rails, etc.
- High visibility worker apparel
- Rumble strips
- Other, please specify (limit 50 characters w/spaces)

Please click the "submit" button to continue with the construction phase survey.

SUBMIT

Roadway Workzone Hazards and Mitigation Strategies

59 During the construction phase, project personnel should identify **"railroads, pedestrian paths/travel routes & trail crossings"** as hazards that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

60 What are the mitigation strategies for **"railroads, pedestrian paths/travel routes & trail crossings"** that could be considered during this project phase? (check all that you agree with)

- Coordination with 3rd Parties (railroad, etc.)
- Monitor ITS effectiveness (deployment monitoring)
- Monitor effectiveness of Traffic Control Plans.
- Provided flaggers, etc. as needed
- Other, please specify (limit 50 characters w/spaces)

61 During the construction phase, project personnel should identify **"increased number of commercial trucks on existing routes or alternate routes"** as a hazard that could contribute to the risk of vehicle crashes & fatalities in workzones.

disagree	agree
1	2

62 What are the mitigation strategies for **"increased number of commercial trucks on existing routes or alternate routes"** that could be considered during this project phase? (check all that you agree with)

- Awareness initiatives, speed control, driver training
- Reflectorized barriers, rails, etc.
- High visibility worker apparel
- Rumble strips
- Other, please specify (limit 50 characters w/spaces)

63 During the construction phase, project personnel should identify **the following** as additional hazards that could contribute to the risk of the vehicle crashes and fatalities in workzones:

Also, list any appropriate mitigation strategies.

Please click the "submit" button to complete the construction phase survey.

SUBMIT

Roadway Workzone Hazards and Mitigation Strategies

64 MTC MIDWEST TRANSPORTATION CONSORTIUM | I STATE | ctre Center for Transportation Research and Education

Please provide any additional comments, concerns or suggestions that you have pertaining to this survey. Your input is greatly appreciated.

For more information or to make any additonal comments please contact the following:

Dan Enz; email enz@iastate.edu

Jennifer Shane; email jsshane@iastate.edu , or phone 515.294.1703.

THANK YOU!

Please click the "submit" button to exit this survey.

SUBMIT

APPENDIX F. INVESTIGATING OFFICER'S REPORT OF MOTOR VEHICLE ACCIDENT

Form 433003
01-01

MAIL REPORTS TO:
Iowa Department of Transportation
Office of Driver Services
Park Fair Mall, 100 Euclid Avenue
P.O. Box 9204
Des Moines, Iowa 50306-9204

PLEASE TYPE OR PRINT

Iowa Department of Transportation
INVESTIGATING OFFICER'S REPORT OF MOTOR VEHICLE ACCIDENT

Sheet ___ of ___
Law Enforcement Case Numbers:
Legal Intervention? ☐ Private Property? ☐

LOCATION

Date of Accident | Time of Accident Hrs. | County | Accident occurred within corporate limits of (city)

If accident occurred outside of city limits show general vicinity ___ miles ○N ○NE ○E ○SE ○S ○SW ○W ○NW of nearest city

On Road, Street, or Highway: | At Intersection with:

Note: Unless accident occurred at an intersection which is completely described above, use the space below to give the exact location from a milepost or definable intersection, bridge, or railroad crossing, using two distances and directions if necessary.

Feet or Miles ○N ○NE ○E ○SE ○S ○SW ○W ○NW and Feet or Miles ○N ○NE ○E ○SE ○S ○SW ○W ○NW of

Milepost Number Or Definable intersection, bridge, or railroad crossing

County: ______ Route: ______
X-Coordinate: ______
Y-Coordinate: ______

If Divided Highway, Provide Route (Cardinal) Travel Direction
NB ○ SB ○ EB ○ WB ○

UNIT 1

Driver's Name (Last, First, Middle) | Address | City | State | Zip

Date of Birth | Driver's License Number | Citation Charge 1. ______ 2. ______ 3. ______ 4. ______

Male ○ Female ○ | State | Class | Endorsements | Restrictions

Alcohol Test Given? |__| 1. None 3. Urine 5. Vitreous 2. Blood 4. Breath 9. Refused Test Results: ______

Drug Test Given? |__| 1. None 3. Urine 2. Blood 9. Refused Pos. ○ Neg. ○

Owner's Name (Last, First, Middle) | Address | City | State | Zip

Insurance Co. Name | Insurance Policy # | License Plate # | State | Year

VIN # | Year | Make | Model | Style | Tow # | Approximate Cost to Repair or Replace $

Initial Travel Direction |__| | Vehicle Action |__|__| | Speed Limit |__|__| | Point of Initial Impact |__|__| | Most Damaged Area |__|__| | Extent of Damage |__| | Underride/Override |__| | Private? ☐

Total Occupants |__|__| | Traffic Controls |__|__| | Vehicle Config. |__|__| | Cargo Body Type |__|__| | Vehicle Defect |__|__| | Driver Condition |__| | Vision Obscured |__|__| | Contributing Circumstances, Driver (up to two) |__|__| |__|__|

Commercial Trailer License Plate # | Attached to Power Unit: | State | Year | Attached to Trailer Unit: | State | Year | Emergency Vehicle Type |__| | Emergency Status |__|

Carrier Name | Address | City | State | Zip

US DOT # ○ or MC # ○ |__|__|__|__|__|__|__|__| | Number of Axles | Gross Vehicle Weight Rating | Placard # |__|__|__|__|-|__| | Hazardous Materials Released? |__|

UNIT 2

Driver's Name (Last, First, Middle) | Address | City | State | Zip

Date of Birth | Driver's License Number | Citation Charge 1. ______ 2. ______ 3. ______ 4. ______

Male ○ Female ○ | State | Class | Endorsements | Restrictions

Alcohol Test Given? |__| 1. None 3. Urine 5. Vitreous 2. Blood 4. Breath 9. Refused Test Results: ______

Drug Test Given? |__| 1. None 3. Urine 2. Blood 9. Refused Pos. ○ Neg. ○

Owner's Name (Last, First, Middle) | Address | City | State | Zip

Insurance Co. Name | Insurance Policy # | License Plate # | State | Year

VIN # | Year | Make | Model | Style | Tow # | Approximate Cost to Repair or Replace $

Initial Travel Direction |__| | Vehicle Action |__|__| | Speed Limit |__|__| | Point of Initial Impact |__|__| | Most Damaged Area |__|__| | Extent of Damage |__| | Underride/Override |__| | Private? ☐

Total Occupants |__|__| | Traffic Controls |__|__| | Vehicle Config. |__|__| | Cargo Body Type |__|__| | Vehicle Defect |__|__| | Driver Condition |__| | Vision Obscured |__|__| | Contributing Circumstances, Driver (up to two) |__|__| |__|__|

Commercial Trailer License Plate # | Attached to Power Unit: | State | Year | Attached to Trailer Unit: | State | Year | Emergency Vehicle Type |__| | Emergency Status |__|

Carrier Name | Address | City | State | Zip

US DOT # ○ or MC # ○ |__|__|__|__|__|__|__|__| | Number of Axles | Gross Vehicle Weight Rating | Placard # |__|__|__|__|-|__| | Hazardous Materials Released? |__|

PROPERTY

If Property other than vehicles damaged explain | Object Damaged | Estimate of Damage $

Owner's Full Name (Last, First, Middle) | Was owner or tenant notified? |__| 1 – Yes 9 - Unknown 2 – No

Street or RFD | City, State, & Zip Code

Unit 1	Unit 2	SEQUENCE OF EVENTS
|__|__|	|__|__|	First Event
|__|__|	|__|__|	Second Event
|__|__|	|__|__|	Third Event
|__|__|	|__|__|	Fourth Event
|__|__|	|__|__|	Most Harmful Event (by vehicle)
|__|__|		First Harmful Event of Crash (use codes 11-42 only)

ACCIDENT ENVIRONMENT
Location of First Harmful Event |__| | Weather Conditions (up to two) |__|__|
Manner of Crash/Collision |__| | |__|__|
Light Conditions |__| | Surface Conditions |__|

ROADWAY CHARACTERISTICS
Major Contributing Circumstances:
Environment |__|
Roadway |__|__|
Type of Roadway Junction/Feature |__|__|

WORKZONE RELATED? ○Yes ○No
|__| Location
|__| Type
|__| Workers Present?

NON-MOTORIST
Type |__| Location |__|
Action |__| Condition |__|
Safety Equipment |__|
Contributing Circumstances |__|__|
Unit No. of Vehicle Striking |__|

Motorcycle Seating Position
01 - Motorcycle Driver
04 - Motorcycle Passenger
88 - Other (explain in narrative)

SEATING POSITION

01	02	03
04	05	06
07	08	09

10 - Sleeper Section
11 - Enclosed Cargo Area
12 - Unenclosed Cargo Area
13 - Trailing Unit
14 - Exterior
15 - Pedestrian
16 - Pedalcyclist
17 - Pedalcyclist, passenger
88 - Other (explain in narrative)
99 - Unknown

Sex | Unit No. | Seating Position | Injury Status | Occupant Protection | Airbag Deployment | Airbag Switch Status | Ejection | Ejection Path | Trapped

DRIVERS

DRIVER OF UNIT 1 — Phone — Transported to: — Transported by:

DRIVER OF UNIT 2 — Phone — Transported to: — Transported by:

PERSONS INJURED

Name 1. — Date of Birth
Address — Transported to: — Transported by:

Name 2. — Date of Birth
Address — Transported to: — Transported by:

Name 3. — Date of Birth
Address — Transported to: — Transported by:

Name 4. — Date of Birth
Address — Transported to: — Transported by:

DIAGRAM

DIAGRAM WHAT HAPPENED: *Instruction*

INDICATE NORTH

Number each vehicle and show direction of travel by arrow:

Use solid line to show path before accident.:

Use dotted line to show path after accident.:

Show pedestrian by.:

Show railroad by.:

Show utility poles by.:

Show motorcycles by.:

Show animal by.:

NARRATIVE

Describe what happened (refer to vehicles by number)

WITNESS

Name (Last, First)	Street or RFD	City	State	Zip	Phone

Signature of Officer | Badge No. | Time Officer Notified of Accident ___ Hrs. | Time Officer Arrived At Scene ___ Hrs.

Name of Agency | Date of Report | Investigation made at scene? Y N | Supplemental Information Will Follow? Y N | T.I. #

Report Reviewed by | Date Reviewed | Report Given to All Drivers? Y N | Other Technical Investigating Agency

Form 433013 01-01

MAIL REPORTS TO:
Iowa Department of Transportation, Office of Driver Services
Park Fair Mall, 100 Euclid Avenue, P.O. Box 9204
Des Moines, Iowa 50306-9204

PLEASE TYPE OR PRINT

Supplemental

Iowa Department of Transportation

INVESTIGATING OFFICER'S REPORT OF MOTOR VEHICLE ACCIDENT

Sheet ___ of ___

Law Enforcement Case Numbers:

Date of Accident | Time of Accident Hrs. | Accident occurred within corporate limits of (city) | On Road, Street, or Highway: | At Intersection with: | County

UNIT ___

Driver's Name (Last, First, Middle) | Address | City | State | Zip

Date of Birth | Driver's License Number | Citation Charge 1. ___ 2. ___ 3. ___ 4. ___

Male ○ Female ○ | State | Class | Endorsements | Restrictions

Alcohol Test Given? [ ] 1. None 2. Blood 3. Urine 4. Breath 5. Vitreous 9. Refused | Test Results: ___

Drug Test Given? [ ] 1. None 2. Blood 3. Urine 9. Refused | Pos. ○ Neg. ○

Owner's Name (Last, First, Middle) | Address | City | State | Zip

Insurance Co. Name | Insurance Policy # | License Plate # | State | Year

VIN # | Year | Make | Model | Style | Tow # | Private ☐ | Approximate Cost to Repair or Replace $

Initial Travel Direction | Vehicle Action | Speed Limit | Point of Initial Impact | Most Damaged Area | Extent of Damage | Underride/Override

Total Occupants | Traffic Controls | Vehicle Config. | Cargo Body Type | Vehicle Defect | Driver Condition | Vision Obscured | Contributing Circumstances, Driver (up to two)

Commercial Trailer License Plate # | Attached to Power Unit: ___ | State | Year | Attached to Trailer Unit: ___ | State | Year | Emergency Vehicle Type | Emergency Status

Carrier Name | Address | City | State | Zip

US DOT # ○ or MC # ○ | Number of Axles | Gross Vehicle Weight Rating | Placard # | Hazardous Materials Released?

UNIT ___

Driver's Name (Last, First, Middle) | Address | City | State | Zip

Date of Birth | Driver's License Number | Citation Charge 1. ___ 2. ___ 3. ___ 4. ___

Male ○ Female ○ | State | Class | Endorsements | Restrictions

Alcohol Test Given? [ ] 1. None 2. Blood 3. Urine 4. Breath 5. Vitreous 9. Refused | Test Results: ___

Drug Test Given? [ ] 1. None 2. Blood 3. Urine 9. Refused | Pos. ○ Neg. ○

Owner's Name (Last, First, Middle) | Address | City | State | Zip

Insurance Co. Name | Insurance Policy # | License Plate # | State | Year

VIN # | Year | Make | Model | Style | Tow # | Private ☐ | Approximate Cost to Repair or Replace $

Initial Travel Direction | Vehicle Action | Speed Limit | Point of Initial Impact | Most Damaged Area | Extent of Damage | Underride/Override

Total Occupants | Traffic Controls | Vehicle Config. | Cargo Body Type | Vehicle Defect | Driver Condition | Vision Obscured | Contributing Circumstances, Driver (up to two)

Commercial Trailer License Plate # | Attached to Power Unit: ___ | State | Year | Attached to Trailer Unit: ___ | State | Year | Emergency Vehicle Type | Emergency Status

Carrier Name | Address | City | State | Zip

US DOT # ○ or MC # ○ | Number of Axles | Gross Vehicle Weight Rating | Placard # | Hazardous Materials Released?

UNIT ___

Driver's Name (Last, First, Middle) | Address | City | State | Zip

Date of Birth | Driver's License Number | Citation Charge 1. ___ 2. ___ 3. ___ 4. ___

Male ○ Female ○ | State | Class | Endorsements | Restrictions

Alcohol Test Given? [ ] 1. None 2. Blood 3. Urine 4. Breath 5. Vitreous 9. Refused | Test Results: ___

Drug Test Given? [ ] 1. None 2. Blood 3. Urine 9. Refused | Pos. ○ Neg. ○

Owner's Name (Last, First, Middle) | Address | City | State | Zip

Insurance Co. Name | Insurance Policy # | License Plate # | State | Year

VIN # | Year | Make | Model | Style | Tow # | Private ☐ | Approximate Cost to Repair or Replace $

Initial Travel Direction | Vehicle Action | Speed Limit | Point of Initial Impact | Most Damaged Area | Extent of Damage | Underride/Override

Total Occupants | Traffic Controls | Vehicle Config. | Cargo Body Type | Vehicle Defect | Driver Condition | Vision Obscured | Contributing Circumstances, Driver (up to two)

Commercial Trailer License Plate # | Attached to Power Unit: ___ | State | Year | Attached to Trailer Unit: ___ | State | Year | Emergency Vehicle Type | Emergency Status

Carrier Name | Address | City | State | Zip

US DOT # ○ or MC # ○ | Number of Axles | Gross Vehicle Weight Rating | Placard # | Hazardous Materials Released?

If Property other than vehicles damaged explain	Object Damaged		Estimate of Damage $
Owner's Full Name (Last, First, Middle)			Was owner or tenant notified? [__] 1 – Yes 2 – No 9 - Unknown
Street or RFD		City, State, & Zip Code	
If Property other than vehicles damaged explain	Object Damaged		Estimate of Damage $
Owner's Full Name (Last, First, Middle)			Was owner or tenant notified? [__] 1 – Yes 2 – No 9 - Unknown
Street or RFD		City, State, & Zip Code	

Unit __	Unit __	Unit __	SEQUENCE OF EVENTS
[__][__]	[__][__]	[__][__]	First Event
[__][__]	[__][__]	[__][__]	Second Event
[__][__]	[__][__]	[__][__]	Third Event
[__][__]	[__][__]	[__][__]	Fourth Event
[__][__]	[__][__]	[__][__]	Most Harmful Event (by vehicle)

NON-MOTORIST

Type [__] Location [__]

Action [__] Condition [__]

Safety Equipment [__]

Contributing Circumstances [__][__]

Unit No. of Vehicle Striking [__]

Motorcycle Seating Position
01 - Motorcycle Driver
04 - Motorcycle Passenger
88 - Other (explain in narrative)

SEATING POSITION

01	02	03
04	05	06
07	08	09

10 - Sleeper Section
11 - Enclosed Cargo Area
12 - Unenclosed Cargo Area
13 - Trailing Unit
14 - Exterior
15 - Pedestrian
16 - Pedalcyclist
17 - Pedalcyclist, passenger
88 - Other (explain in narrative)
99 - Unknown

Columns: Sex | Unit No. | Seating Position | Injury Status | Occupant Protection | Airbag Deployment | Airbag Switch Status | Ejection | Ejection Path | Trapped

DRIVERS

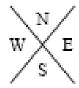
DRIVER OF UNIT ___	Phone		
	Transported to:	Transported by:	
DRIVER OF UNIT ___	Phone		
	Transported to:	Transported by:	
DRIVER OF UNIT ___	Phone		
	Transported to:	Transported by:	

PERSONS INJURED

Name	Date of Birth	
Address	Transported to:	Transported by:
Name	Date of Birth	
Address	Transported to:	Transported by:
Name	Date of Birth	
Address	Transported to:	Transported by:
Name	Date of Birth	
Address	Transported to:	Transported by:
Name	Date of Birth	
Address	Transported to:	Transported by:
Name	Date of Birth	
Address	Transported to:	Transported by:
Name	Date of Birth	
Address	Transported to:	Transported by:
Name	Date of Birth	
Address	Transported to:	Transported by:
Name	Date of Birth	
Address	Transported to:	Transported by:
Name	Date of Birth	
Address	Transported to:	Transported by:
Name	Date of Birth	
Address	Transported to:	Transported by:

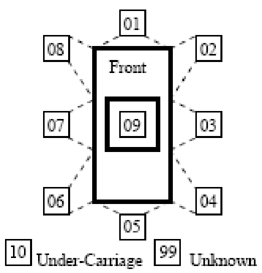
Driver/Vehicle Characteristics

Initial Travel Direction
(prior to coded Vehicle Action)
1 - North
2 - East
3 - South
4 - West
9 - Unknown



Vehicle Action
01 - Movement essentially straight
02 - Turning left
03 - Turning right
04 - Making U-turn
05 - Overtaking/passing
06 - Changing lanes
07 - Entering traffic lane (merging)
08 - Leaving traffic lane
09 - Backing
10 - Slowing/stopping
11 - Stopped for stop sign/signal
12 - Legally Parked
13 - Illegally Parked/Unattended
88 - Other (explain in narrative)
99 - Unknown

Point of Initial Impact
Most Damaged Area



Extent of Damage
1 - None
2 - Minor damage
3 - Functional damage
4 - Disabling damage
5 - Severe, vehicle totaled
9 - Unknown

Underride/Override
1 - None
2 - Underride, compartment intrusion
3 - Underride, no compartment intrusion
4 - Underride, compartment intrusion unknown
5 - Override, moving vehicle
6 - Override, parked/stationary vehicle
9 - Unknown

Traffic Controls
01 - No controls present
02 - Traffic signals
03 - Flashing traffic control signal
04 - Stop signs
05 - Yield signs
06 - No Passing Zone (marked)
07 - Warning sign
08 - School zone signs
09 - Railway crossing device
10 - Traffic director
11 - Workzone signs
88 - Other control (explain in narrative)
99 - Unknown

Vehicle Configuration
01 - Passenger car
02 - Four-tire light truck (pick-up, panel)
03 - Van or mini-van
04 - Sport utility vehicle
05 - Single-unit truck (2-axle, 6-tire)
06 - Single-unit truck (>= 3 axles)
07 - Truck/trailer
08 - Truck tractor (bobtail)
09 - 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
88 - Other (explain in narrative)
99 - Unknown

Cargo Body Type
01 - Not applicable

Truck Cargo Type:
02 - Van/enclosed box
03 - Dump truck (grain, gravel)
04 - Cargo tank
05 - Flatbed
06 - Concrete mixer
07 - Auto transporter
08 - Garbage/refuse
09 - Other truck cargo type (explain in narrative)

Trailer type:
10 - Small utility (one axle)
11 - Large utility (2+ axles)
12 - Boat
13 - Camper
14 - Large mobile home
15 - Oversize load
16 - Towed vehicle
17 - Pole
18 - Other trailer type (explain in narrative)
99 - Unknown

Vehicle Defect
01 - None
02 - Brakes
03 - Steering
04 - Blowout
05 - Other tire defect (explain in narrative)
06 - Wipers
07 - Trailer hitch
08 - Exhaust
09 - Headlights
10 - Tail lights
11 - Turn signal
12 - Suspension
88 - Other (explain in narrative)
99 - Unknown

Driver Condition
1 - Apparently normal
2 - Physical impairment
3 - Emotional (e.g., depressed, angry, disturbed)
4 - Illness
5 - Asleep, fainted, fatigued, etc.
6 - Under the influence of alcohol/drugs/medications
8 - Other (explain in narrative)
9 - Unknown

Vision Obscured
01 - Not obscured
02 - Trees/crops
03 - Buildings
04 - Embankment
05 - Sign/billboard
06 - Hillcrest
07 - Parked vehicles
08 - Moving vehicles
09 - Person/object in or on vehicle
10 - Blinded by sun or headlights
11 - Frosted windows/windshield
12 - Blowing snow
13 - Fog/smoke/dust
88 - Other (explain in narrative)
99 - Unknown

Contributing Circumstances, Driver (up to two)
01 - Ran traffic signal
02 - Ran stop sign
03 - Exceeded authorized speed
04 - Driving too fast for conditions
05 - Made improper turn
06 - Traveling wrong way or on wrong side of road
07 - Crossed centerline
08 - Lost Control
09 - Followed too close
10 - Swerved to avoid: vehicle, object, non-motorist, or animal in roadway
11 - Over correcting/over steering
12 - Operating vehicle in an erratic, reckless, careless, negligent, or aggressive manner

Failed to yield right-of-way:
13 - From stop sign
14 - From yield sign
15 - Making left turn
16 - Making right turn on red signal
17 - From driveway
18 - From parked position
19 - To pedestrian
20 - At uncontrolled intersection
21 - Other (explain in narrative)

Inattentive/distracted by:
22 - Passenger
23 - Use of phone or other device
24 - Fallen object
25 - Fatigued/asleep

Other (explain in narrative):
26 - Vision obstructed
27 - Other improper action
28 - No improper action

99 - Unknown

Emergency Vehicles

Emergency Vehicle Type
1 - Not applicable
2 - Police
3 - Fire
4 - Ambulance
5 - Towing
6 - Military
7 - Maintenance
9 - Unknown

Emergency Status
1 - Yes, in emergency
2 - No, not in emergency
3 - Not applicable
9 - Unknown

Hazardous Materials Released? (Cargo Only)
1 - Yes
2 - No
3 - Not applicable
9 - Unknown

Iowa Department of Transportation

INVESTIGATING OFFICER'S REPORT OF MOTOR VEHICLE ACCIDENT CODE SHEET

Form 433014
01-01

Workzone Related?

Location
1 - Before work zone warning sign
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

Type
1 - Lane closure
2 - Lane shift/crossover (head-to-head traffic)
3 - Work on shoulder or median
4 - Intermittent or moving work
8 - Other type of work zone (explain in narrative)
9 - Unknown

Workers Present?
1 - Yes
2 - No
9 - Unknown

Accident Environment

Location of First Harmful Event
1 - On Roadway
2 - Shoulder
3 - Median
4 - Roadside
5 - Gore
6 - Outside trafficway
9 - Unknown

Manner of Crash/Collision
1 - Non-collision
2 - Head-on
3 - Rear-end
4 - Angle, oncoming left turn
5 - Broadside
6 - Sideswipe, same direction
7 - Sideswipe, opposite direction
9 - Unknown

Light Conditions
1 - Daylight
2 - Dusk
3 - Dawn
4 - Dark, roadway lighted
5 - Dark, roadway not lighted
6 - Dark, unknown roadway lighting
9 - Unknown

Weather Conditions (up to two)
01 - Clear
02 - Partly cloudy
03 - Cloudy
04 - Fog, smoke
05 - Mist
06 - Rain
07 - Sleet, hail, freezing rain
08 - Snow
09 - Severe winds
10 - Blowing sand, soil, dirt, snow
88 - Other (explain in narrative)
99 - Unknown

Surface Conditions
1 - Dry
2 - Wet
3 - Ice
4 - Snow
5 - Slush
6 - Sand, mud, dirt, oil, gravel
7 - Water (standing, moving)
8 - Other (explain in narrative)
9 - Unknown

Roadway Characteristics

Contributing Circumstances, Environment
1 - None apparent
2 - Weather conditions
3 - Physical obstruction
4 - Pedestrian action
5 - Glare
6 - Animal in roadway
7 - Previous accident
8 - Other (explain in narrative)
9 - Unknown

Contributing Circumstances, Roadway
01 - None apparent
02 - Road surface condition
03 - Debris
04 - Ruts, holes, bumps
05 - Work Zone (construction, maintenance, utility)
06 - Worn, travel-polished surface
07 - Obstruction in roadway
08 - Traffic control device inoperative, missing, obscured
09 - Shoulders (none, low, soft, high)
10 - Non-highway work
11 - Non-contact vehicle
99 - Unknown

Type of Roadway Junction/Feature
Non-intersection:
01 - No special feature
02 - Bridge/overpass/underpass
03 - Railroad crossing
04 - Business drive
05 - Farm/residential drive
06 - Alley intersection
07 - Crossover in median
08 - Other non-intersection (explain in narrative)
Intersection:
11 - Four-way intersection
12 - T - intersection
13 - Y - intersection
14 - Five-leg or more
15 - Offset four-way intersection
16 - Intersection with ramp
17 - On-ramp merge area
18 - Off-ramp diverge area
19 - On-ramp
20 - Off-ramp
21 - With bike/pedestrian path
22 - Other intersection (explain in narrative)
99 - Unknown

Harmful Events

Sequence of Events
Most Harmful Event
First Harmful Event
Pre-crash events:
01 - Ran off road, right
02 - Ran off road, straight
03 - Ran off road, left
04 - Crossed centerline/median
05 - Animal or object in roadway
06 - Evasive action (swerve, panic braking, etc.)
07 - Downhill runaway
08 - Cargo/equipment loss or shift
09 - Equipment failure (tires, brakes, etc.)
10 - Separation of units
Non-collision events:
11 - Overturn/rollover
12 - Jackknife
13 - Other non-collision (explain in narrative)
Collision with:
20 - Non-motorist (see non-motorist type)
21 - Vehicle in traffic
22 - Vehicle in/from other roadway
23 - Parked motor vehicle
24 - Railway vehicle/train
25 - Animal
26 - Other non-fixed object (explain in narrative)
Collision with fixed object:
30 - Bridge/bridge rail/overpass
31 - Underpass/structure support
32 - Culvert
33 - Ditch/embankment
34 - Curb/island/raised median
35 - Guardrail
36 - Concrete barrier (median or right side)
37 - Tree
38 - Poles (utility, light, etc.)
39 - Sign post
40 - Mailbox
41 - Impact attenuator
42 - Other fixed object (explain in narrative)
Misc. events:
50 - Fire/explosion
51 - Immersion
52 - Hit and run
99 - Unknown

Injury/Protective Devices

Injury Status
1 - Fatal
2 - Incapacitating
3 - Non-incapacitating
4 - Possible
5 - Uninjured
9 - Unknown

Occupant Protection
1 - None used
2 - Shoulder and lap belt used
3 - Lap belt only used
4 - Shoulder belt only used
5 - Child safety seat used
6 - Helmet used
8 - Other (explain in narrative)
9 - Unknown

Airbag Deployment
1 - Deployed front of person
2 - Deployed side of person
3 - Deployed both front/side
4 - Other deployment (explain in narrative)
5 - Not deployed
6 - Not applicable
9 - Unknown

Airbag Switch Status
1 - Switch in ON position
2 - Switch in OFF position
3 - No ON/OFF switch present
9 - Unknown

Ejection
1 - Not ejected
2 - Partially ejected
3 - Totally ejected
4 - Not applicable (motorcycle, bicycle, etc.)
9 - Unknown

Ejection Path
1 - Not ejected/not applicable
2 - Through front windshield
3 - Through side window/door
4 - Through roof
5 - Through back window/tailgate
9 - Unknown

Trapped
1 - Not trapped
2 - Freed by non-mechanical means
3 - Extricated by mechanical means
9 - Unknown

Non-Motorist

Type
1 - Pedestrian
2 - Pedalcyclist (bicycle, tricycle, unicycle, pedal car)
3 - Skater
8 - Other (explain in narrative)
9 - Unknown

Location (prior to impact)
1 - Marked crosswalk at intersection
2 - At intersection, no crosswalk
3 - Non-intersection crosswalk
4 - Driveway access crosswalk
8 - Other non-intersection (explain in narrative)
9 - Unknown

Action
1 - Entering or crossing roadway
2 - Walking, running, jogging, playing, cycling
3 - Working
4 - Pushing vehicle
5 - Approaching or leaving vehicle
6 - Playing or working on vehicle
7 - Standing
8 - Other (explain in narrative)
9 - Unknown

Condition
1 - Apparently normal
2 - Physical impairment
3 - Emotional (e.g., depressed, angry, disturbed)
4 - Illness
5 - Asleep, fainted, fatigued, etc.
6 - Under the influence of alcohol/drugs/medications
8 - Other (explain in narrative)
9 - Unknown

Safety Equipment
1 - Helmet
2 - Reflective clothing
3 - Lighting
4 - None
8 - Other (explain in narrative)
9 - Unknown

Contributing Circumstances
01 - Improper crossing
02 - Darting
03 - Lying or sitting in roadway
04 - Failure to yield right of way
05 - Not visible (dark clothing)
06 - Inattentive (talking, eating, etc.)
07 - Failure to obey traffic signs, signals, or officer
08 - Wrong side of road
88 - Other (explain in narrative)
99 - Unknown

APPENDIX G. WORK ZONE CRASH DATABASE PARAMETERS

Work Zone Crash Parameters (zwks)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique Identifier		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
WZ_Related	Workzone Related?			Character	1	0
		1	Yes			
		2	No			
WZ_Loc	Location			Numeric: Integer	2	0
		1	Before work zone warning sign			
		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.			
WZ_Type	Type			Numeric: Integer	2	0
		1	Lane closure			
		2	Lane shift/crossover (head-to-head traffic)			
		3	Work on shoulder or median			
		4	Intermittent or moving work			
		8	Other type of work zone (explain in narrative)			
		9	Unknown			
		77	Not reported.			
Workers	Workers Present?			Numeric: Integer	2	0
		1	Yes			
		2	No			
		9	Unknown			
		77	Not reported.			

Crash Type Parameters 1 (zcta)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique Identifier		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
FirstHarm	First Harmful Event			Numeric: Integer	2	0
		11	Non-collision events: Overturn/rollover			
		12	Non-collision events: Jackknife			
		13	Non-collision events: Other non-collision (explain in narrative)			
		20	Collision with: Non-motorist (see non-motorist type)			
		21	Collision with: Vehicle in traffic			
		22	Collision with: Vehicle in/from other roadway			
		23	Collision with: Parked motor vehicle			
		24	Collision with: Railway vehicle/train			
		25	Collision with: Animal			
		26	Collision with: Other non-fixed object (explain in narrative)			
		30	Collision with fixed object: Bridge/bridge rail/overpass			
		31	Collision with fixed object: Underpass/structure support			
		32	Collision with fixed object: Culvert			
		33	Collision with fixed object: Ditch/embankment			
		34	Collision with fixed object: Curb/island/raised median			
		35	Collision with fixed object: Guardrail			
		36	Collision with fixed object: Concrete barrier (median or right side)			
		37	Collision with fixed object: Tree			
		38	Collision with fixed object: Poles (utility, light, etc.)			
		39	Collision with fixed object: Sign post			
		40	Collision with fixed object: Mailbox			
		41	Collision with fixed object: Impact attenuator			
		42	Collision with fixed object: Other fixed object (explain in narrative)			
		50	Miscellaneous events: Fire/explosion			
		51	Miscellaneous events: Immersion			
		52	Miscellaneous events: Hit and run			
		77	Not Reported			
		99	Unknown			
CrCoManner	Manner of Crash/Collision			Numeric: Integer	2	0
		1	Non-collision			
		2	Head-on			
		3	Rear-end			
		4	Angle, oncoming left turn			
		5	Broadside			
		6	Sideswipe, same direction			
		7	Sideswipe, opposite direction			
		9	Unknown			
		77	Not Reported			

Crash Type Parameters 1 (zcta) – cont.

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
MajorCause	Major Cause		Derived.	Numeric: Integer	2	0
		1	Animal			
		2	Ran Traffic Signal			
		3	Ran Stop Sign			
		4	Crossed centerline			
		5	FTYROW: At uncontrolled intersection			
		6	FTYROW: Making right turn on red signal			
		7	FTYROW: From stop sign			
		8	FTYROW: From yield sign			
		9	FTYROW: Making left turn			
		10	FTYROW: From driveway			
		11	FTYROW: From parked position			
		12	FTYROW: To pedestrian			
		13	FTYROW: Other (explain in narrative)			
		14	Traveling wrong way or on wrong side of road			
		15	Driving too fast for conditions			
		16	Exceeded authorized speed			
		17	Made improper turn			
		18	Improper Lane Change			
		19	Followed too close			
		20	Disregarded RR Signal			
		21	Disregarded Warning Sign			
		22	Operating vehicle in an erratic/reckless/careless/negligent/aggressive manner			
		23	Improper Backing			
		24	Illegally Parked/Unattended			
		25	Swerving/Evasive Action			
		26	Over correcting/over steering			
		27	Downhill runaway			
		28	Equipment failure			
		29	Separation of units			
		30	Ran off road - right			
		31	Ran off road - straight			
		32	Ran off road - left			
		33	Lost Control			
		34	Inattentive/distracted by: Passenger			
		35	Inattentive/distracted by: Use of phone or other device			
		36	Inattentive/distracted by: Fallen object			
		37	Inattentive/distracted by: Fatigued/asleep			
		38	Other (explain in narrative): Vision obstructed			
		39	Oversized Load/Vehicle			
		40	Cargo/equipment loss or shift			
		41	Other (explain in narrative): Other improper action			
		42	Unknown			
		43	Other (explain in narrative): No improper action			
		77	Not Reported			
DrugAlcRel	Drug or Alcohol Related		Derived from Alcohol results, Drug results, and driver conditions.	Numeric: Integer	1	0
		1	Drug-related			
		2	Alcohol-related (under 0.08)			
		3	Alcohol-related (0.08 or over)			
		4	Drug- and alcohol-related (under 0.08)			
		5	Drug- and alcohol-related (0.08 or over)			
		6	Refused			
		7	A driver indicated as under the influence of alcohol/drugs/medications			
		8	Not drug- or alcohol-related			

Severity Level Crash Parameters (zsev)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
CSeverity	Crash Severity			Numeric: Integer	1	0
		1	Fatal			
		2	Major Injury			
		3	Minor Injury			
		4	Possible/Unknown			
		5	Property Damage Only			
Fatalities	Number of Fatalities		Crashwide total of all fatalities.	Numeric: Integer	3	0
Injuries	Number of Injuries		Crashwide total of all injuries, excluding fatalities.	Numeric: Integer	3	0
MajInjury	Number of Major Injuries		Crashwide total of all major injuries.	Numeric: Integer	3	0
MinInjury	Number of Minor Injuries		Crashwide total of all minor injuries.	Numeric: Integer	3	0
PossInjury	Number of Possible Injuries		Crashwide total of all possible injuries.	Numeric: Integer	3	0
UnkInjury	Number of Unknown Injuries		Crashwide total of all unknown injuries.	Numeric: Integer	3	0
PropDmg	Amount of Property Damage		Crashwide total of property damage, including non-vehicular.	Numeric: Integer	9	0
Vehicles	Number of Vehicles		Number of vehicles involved in the crash.	Numeric: Integer	2	0
TOccupants	Total Number of Occupants		Crashwide total of occupants in all vehicles.	Numeric: Integer	3	0

Location/Time Crash Parameters (zltp)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique Identifier		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
Date	Date of Crash		Crash date in YYYYMMDD format (e.g., 20010422)	Numeric: Integer	8	0
Month	Month			Numeric: Integer	2	0
		1	January			
		2	February			
		3	March			
		4	April			
		5	May			
		6	June			
		7	July			
		8	August			
		9	September			
		10	October			
		11	November			
		12	December			
DayOfMonth	Day of Month	1-31	Valid values depend on month and year (leap year).	Numeric: Integer	2	0
Year	Year			Numeric: Integer	4	0
Day	Day of Week			Numeric: Integer	1	0
		1	Sunday			
		2	Monday			
		3	Tuesday			
		4	Wednesday			
		5	Thursday			
		6	Friday			
		7	Saturday			
Time	Time of Crash		Crash time in 24-hour format (HHMM) (e.g., 1230)	Numeric: Integer	4	0
TimeStr	Time of Crash in String Format		Crash time in 24-hour format (HH:MM) (e.g., 12:30)	String	5	0

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
TimeDay	Time of Day/Day of Week in Bins		Time of Day and Day of Week combined and into bin definitions	Numeric: Integer	3	0
		101	Sunday, 12 midnight to 1:59 AM			
		201	Monday, 12 midnight to 1:59 AM			
		301	Tuesday, 12 midnight to 1:59 AM			
		401	Wednesday, 12 midnight to 1:59 AM			
		501	Thursday, 12 midnight to 1:59 AM			
		601	Friday, 12 midnight to 1:59 AM			
		701	Saturday, 12 midnight to 1:59 AM			
		102	Sunday, 2:00 AM to 3:59 AM			
		202	Monday, 2:00 AM to 3:59 AM			
		302	Tuesday, 2:00 AM to 3:59 AM			
		402	Wednesday, 2:00 AM to 3:59 AM			
		502	Thursday, 2:00 AM to 3:59 AM			
		602	Friday, 2:00 AM to 3:59 AM			
		702	Saturday, 2:00 AM to 3:59 AM			
		103	Sunday, 4:00 AM to 5:59 AM			
		203	Monday, 4:00 AM to 5:59 AM			
		303	Tuesday, 4:00 AM to 5:59 AM			
		403	Wednesday, 4:00 AM to 5:59 AM			
		503	Thursday, 4:00 AM to 5:59 AM			
		603	Friday, 4:00 AM to 5:59 AM			
		703	Saturday, 4:00 AM to 5:59 AM			
		104	Sunday, 6:00 AM to 7:59 AM			
		204	Monday, 6:00 AM to 7:59 AM			
		304	Tuesday, 6:00 AM to 7:59 AM			
		404	Wednesday, 6:00 AM to 7:59 AM			
		504	Thursday, 6:00 AM to 7:59 AM			
		604	Friday, 6:00 AM to 7:59 AM			
		704	Saturday, 6:00 AM to 7:59 AM			
		105	Sunday, 8:00 AM to 9:59 AM			
		205	Monday, 8:00 AM to 9:59 AM			
		305	Tuesday, 8:00 AM to 9:59 AM			
		405	Wednesday, 8:00 AM to 9:59 AM			
		505	Thursday, 8:00 AM to 9:59 AM			
		605	Friday, 8:00 AM to 9:59 AM			
		705	Saturday, 8:00 AM to 9:59 AM			
		106	Sunday, 10:00 AM to 11:59 AM			
		206	Monday, 10:00 AM to 11:59 AM			
		306	Tuesday, 10:00 AM to 11:59 AM			
		406	Wednesday, 10:00 AM to 11:59 AM			
		506	Thursday, 10:00 AM to 11:59 AM			
		606	Friday, 10:00 AM to 11:59 AM			
		706	Saturday, 10:00 AM to 11:59 AM			
		107	Sunday, 12:00 noon to 1:59 PM			
		207	Monday, 12:00 noon to 1:59 PM			
		307	Tuesday, 12:00 noon to 1:59 PM			
		407	Wednesday, 12:00 noon to 1:59 PM			
		507	Thursday, 12:00 noon to 1:59 PM			
		607	Friday, 12:00 noon to 1:59 PM			
		707	Saturday, 12:00 noon to 1:59 PM			
		108	Sunday, 2:00 PM to 3:59 PM			
		208	Monday, 2:00 PM to 3:59 PM			
		308	Tuesday, 2:00 PM to 3:59 PM			
		408	Wednesday, 2:00 PM to 3:59 PM			
		508	Thursday, 2:00 PM to 3:59 PM			
		608	Friday, 2:00 PM to 3:59 PM			
		708	Saturday, 2:00 PM to 3:59 PM			
		109	Sunday, 4:00 PM to 5:59 PM			
		209	Monday, 4:00 PM to 5:59 PM			
		309	Tuesday, 4:00 PM to 5:59 PM			
		409	Wednesday, 4:00 PM to 5:59 PM			
		509	Thursday, 4:00 PM to 5:59 PM			
		609	Friday, 4:00 PM to 5:59 PM			
		709	Saturday, 4:00 PM to 5:59 PM			
		110	Sunday, 6:00 PM to 7:59 PM			
		210	Monday, 6:00 PM to 7:59 PM			
		310	Tuesday, 6:00 PM to 7:59 PM			
		410	Wednesday, 6:00 PM to 7:59 PM			
		510	Thursday, 6:00 PM to 7:59 PM			
		610	Friday, 6:00 PM to 7:59 PM			
		710	Saturday, 6:00 PM to 7:59 PM			
		111	Sunday, 8:00 PM to 9:59 PM			
		211	Monday, 8:00 PM to 9:59 PM			
		311	Tuesday, 8:00 PM to 9:59 PM			
		411	Wednesday, 8:00 PM to 9:59 PM			
		511	Thursday, 8:00 PM to 9:59 PM			
		611	Friday, 8:00 PM to 9:59 PM			
		711	Saturday, 8:00 PM to 9:59 PM			
		112	Sunday, 10:00 PM to 11:59 PM			
		212	Monday, 10:00 PM to 11:59 PM			
		312	Tuesday, 10:00 PM to 11:59 PM			
		412	Wednesday, 10:00 PM to 11:59 PM			
		512	Thursday, 10:00 PM to 11:59 PM			
		612	Friday, 10:00 PM to 11:59 PM			
		712	Saturday, 10:00 PM to 11:59 PM			
		113	Sunday, unknown time			
		213	Monday, unknown time			
		313	Tuesday, unknown time			
		413	Wednesday, unknown time			
		513	Thursday, unknown time			
		613	Friday, unknown time			
		713	Saturday, unknown time			

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
LocFstHarm	Location of First Harmful Event			Numeric: Integer	2	0
		1	On Roadway			
		2	Shoulder			
		3	Median			
		4	Roadside			
		5	Gore			
		6	Outside trafficway			
		9	Unknown			
		77	Not reported.			
RuralUrban	Rural/Urban			Character	1	0
		R	Rural			
		U	Urban			

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
County	County			Numeric: Integer	2	0
		1	Adair			
		2	Adams			
		3	Allamakee			
		4	Appanoose			
		5	Audubon			
		6	Benton			
		7	Black Hawk			
		8	Boone			
		9	Bremer			
		10	Buchanan			
		11	Buena Vista			
		12	Butler			
		13	Calhoun			
		14	Carroll			
		15	Cass			
		16	Cedar			
		17	Cerro Gordo			
		18	Cherokee			
		19	Chickasaw			
		20	Clarke			
		21	Clay			
		22	Clayton			
		23	Clinton			
		24	Crawford			
		25	Dallas			
		26	Davis			
		27	Decatur			
		28	Delaware			
		29	Des Moines			
		30	Dickinson			
		31	Dubuque			
		32	Emmet			
		33	Fayette			
		34	Floyd			
		35	Franklin			
		36	Fremont			
		37	Greene			
		38	Grundy			
		39	Guthrie			
		40	Hamilton			
		41	Hancock			
		42	Hardin			
		43	Harrison			
		44	Henry			
		45	Howard			
		46	Humboldt			
		47	Ida			
		48	Iowa			
		49	Jackson			
		50	Jasper			
		51	Jefferson			
		52	Johnson			
		53	Jones			
		54	Keokuk			
		55	Kossuth			
		56	Lee			
		57	Linn			
		58	Louisa			
		59	Lucas			
		60	Lyon			
		61	Madison			
		62	Mahaska			
		63	Marion			
		64	Marshall			
		65	Mills			
		66	Mitchell			
		67	Monona			
		68	Monroe			
		69	Montgomery			
		70	Muscatine			
		71	O'Brien			
		72	Osceola			
		73	Page			
		74	Palo Alto			
		75	Plymouth			
		76	Pocahontas			
		77	Polk			
		78	Pottawattamie			

		79	Poweshiek			
		80	Ringgold			
		81	Sac			
		82	Scott			
		83	Shelby			
		84	Sioux			
		85	Story			
		86	Tama			
		87	Taylor			
		88	Union			
		89	Van Buren			
		90	Wapello			
		91	Warren			
		92	Washington			
		93	Wayne			
		94	Webster			
		95	Winnebago			
		96	Winneshiek			
		97	Woodbury			
		98	Worth			
		99	Wright			

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
City	City		Crash records city number. Unique within a county.	Numeric: Integer	2	0
CityBR	Base Records City Number		City number from Base Records.	Numeric: Integer	4	0
CityName	City Name		Text city name.	Character	25	0
Cardinal	Cardinal Travel Direction		Primary direction of travel for the route.	Character	2	0
		NB	Northbound (NB)			
		SB	Southbound (SB)			
		EB	Eastbound (EB)			
		WB	Westbound (WB)			
Route	Route Number			Character	3	0
		Route #	(e.g., 030 = US 30, 035 = Interstate 35)			
		"A" - "Z" + ##	County Road with Route Designator Noted			
		990	County Road			
		991	County Park			
		995	City Street			
		996	City Park, Frontage, Alley			
Milepoint	Milepoint		Milepoint along primary highways.	Numeric: Decimal	6	2
Milepost	Milepost		Milepost along primary highways.	Numeric: Decimal	6	2

Roadway Crash Parameters 1 (zrda)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
Road_Class	Road Classification	1	Interstate	Numeric: Integer	1	0
		2	US or State Highway			
		3	County Road			
		4	City Street			
		5	Other			
		77	Not Reported			
		99	Unknown			
IntClass	Intersection Class			Numeric: Integer	2	0
		1	Interstate/Interstate			
		2	Interstate/US or State Highway			
		3	Interstate/City or County Road			
		4	US or State Highway/US or State Highway			
		5	US or State Highway/County Road or City Street			
		6	US or State Highway/Other			
		7	County Road or City Street/County Road or City Street			
		8	County Road or City Street/Other			
		77	Not reported.			
		99	Not an Intersection (Unknown)			
RContCirc	Contributing Circumstances - Roadway			Numeric: Integer	2	0
		1	None apparent			
		2	Road surface condition			
		3	Debris			
		4	Ruts/holes/bumps			
		5	Work Zone (construction/maintenance/utility)			
		6	Worn/travel-polished surface			
		7	Obstruction in roadway			
		8	Traffic control device inoperative/missing/obscured			
		9	Shoulders (none/low/soft/high)			
		10	Non-highway work			
		11	Non-contact vehicle			
		77	Not reported.			
		99	Unknown			
RoadType	Type of Roadway Junction/Feature			Numeric: Integer	2	0
		1	Non-intersection: No special feature			
		2	Non-intersection: Bridge/overpass/underpass			
		3	Non-intersection: Railroad crossing			
		4	Non-intersection: Business drive			
		5	Non-intersection: Farm/residential drive			
		6	Non-intersection: Alley intersection			
		7	Non-intersection: Crossover in median			
		8	Non-intersection: Other non-intersection (explain in narrative)			
		11	Intersection: Four-way intersection			
		12	Intersection: T - intersection			
		13	Intersection: Y - intersection			
		14	Intersection: Five-leg or more			
		15	Intersection: Offset four-way intersection			
		16	Intersection: Intersection with ramp			
		17	Intersection: On-ramp merge area			
		18	Intersection: Off-ramp diverge area			
		19	Intersection: On-ramp			
		20	Intersection: Off-ramp			
		21	Intersection: With bike/pedestrian path			
		22	Intersection: Other intersection (explain in narrative)			
		77	Not reported.			
		99	Unknown			
RoadGeo	Roadway Geometrics			Numeric: Integer	2	0
		1	Straight and Level			
		2	Straight and Up/Downgrade			
		3	Straight and Hillcrest			
		4	Curve and Level			
		5	Curve and Up/Downgrade			
		6	Curve and Hillcrest			
		7	Intersection and Level			
		8	Intersection and Up/Downgrade			
		9	Intersection and Hillcrest			
		77	Not reported.			
		99	Unknown			

Environmental Crash Parameters (zenv)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique Identifier		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
EContCirc	Contributing Circumstances - Environment			Numeric: Integer	2	0
		1	None apparent			
		2	Weather conditions			
		3	Physical obstruction			
		4	Pedestrian action			
		5	Glare			
		6	Animal in roadway			
		7	Previous accident			
		8	Other (explain in narrative)			
		9	Unknown			
		77	Not Reported			
Weather1	Weather Conditions 1			Numeric: Integer	2	0
		1	Clear			
		2	Partly cloudy			
		3	Cloudy			
		4	Fog/smoke			
		5	Mist			
		6	Rain			
		7	Sleet/hail/freezing rain			
		8	Snow			
		9	Severe winds			
		10	Blowing sand/soil/dirt/snow			
		77	Not Reported			
		88	Other (explain in narrative)			
		99	Unknown			
Weather2	Weather Conditions 2		See Weather1 values.	Numeric: Integer	2	0
Light	Light Conditions			Numeric: Integer	2	0
		1	Daylight			
		2	Dusk			
		3	Dawn			
		4	Dark - roadway lighted			
		5	Dark - roadway not lighted			
		6	Dark - unknown roadway lighting			
		9	Unknown			
		77	Not Reported			
Locality	Locality		Not currently in crash data.		2	
		77	Not Reported			
CSurfCond	Surface Conditions		Crashwide surface conditions.	Numeric: Integer	2	0
		1	Dry			
		2	Wet			
		3	Ice			
		4	Snow			
		5	Slush			
		6	Sand/mud/dirt/oil/gravel			
		7	Water (standing/moving)			
		8	Other (explain in narrative)			
		9	Unknown			
		77	Not Reported			

Vehicle Crash Parameters (zveh)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
V1UnitNum	Vehicle Unit Number		Number indicating which vehicle the driver was operating.	Numeric: Integer	3	0
		777	Not reported.			
V1UnitKey	Combined Crash_Key and V1UnitNum		Crash_Key*1000+V1UnitNum	Numeric: Integer	13	0
VConfig	Vehicle Configuration			Numeric: Integer	2	0
		1	Passenger car			
		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			
VYear	Vehicle Year		Vehicle year in YYYY format.	Numeric: Integer	4	0
		7777	Not reported.			
Make	Vehicle Make		(currently undefined)	Character	4	0
Model	Vehicle Model		(currently undefined)	Character	12	0
Style	Vehicle Style		(currently undefined)	Character	12	0
EmerVeh	Emergency Vehicle Type			Numeric: Integer	2	0
		1	Not applicable			
		2	Police			
		3	Fire			
		4	Ambulance			
		5	Towing			
		6	Military			
		7	Maintenance			
		9	Unknown			
		77	Not reported.			
EmerStatus	Emergency Status			Numeric: Integer	2	0
		1	Yes - in emergency			
		2	No - not in emergency			
		3	Not applicable			
		9	Unknown			
		77	Not reported.			
Occupants	Total Occupants		Occupants in vehicle.	Numeric: Integer	2	0
		777	Not reported.			
CargoBody	Cargo Body Type			Numeric: Integer	2	0
		1	Not applicable			
		2	Truck Cargo Type: Van/enclosed box			
		3	Truck Cargo Type: Dump truck (grain/gravel)			
		4	Truck Cargo Type: Cargo tank			
		5	Truck Cargo Type: Flatbed			
		6	Truck Cargo Type: Concrete mixer			
		7	Truck Cargo Type: Auto transporter			
		8	Truck Cargo Type: Garbage/refuse			
		9	Truck Cargo Type: Other truck cargo type (explain in narrative)			
		10	Trailer type: Small utility (one axle)			
		11	Trailer type: Large utility (2+ axles)			
		12	Trailer type: Boat			
		13	Trailer type: Camper			
		14	Trailer type: Large mobile home			
		15	Trailer type: Oversize load			
		16	Trailer type: Towed vehicle			
		17	Trailer type: Pole			
		18	Trailer type: Other trailer type (explain in narrative)			
		77	Not reported.			
		99	Unknown			

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Defect	Vehicle Defect			Numeric: Integer	2	0
		1	None			
		2	Brakes			
		3	Steering			
		4	Blowout			
		5	Other tire defect (explain in narrative)			
		6	Wipers			
		7	Trailer hitch			
		8	Exhaust			
		9	Headlights			
		10	Tail lights			
		11	Turn signal			
		12	Suspension			
		77	Not reported.			
		88	Other (explain in narrative)			
		99	Unknown			
InitDir	Initial Direction of Travel			Numeric: Integer	2	0
		1	North			
		2	East			
		3	South			
		4	West			
		9	Unknown			
		77	Not reported.			
VAction	Vehicle Action			Numeric: Integer	2	0
		1	Movement essentially straight			
		2	Turning left			
		3	Turning right			
		4	Making U-turn			
		5	Overtaking/passing			
		6	Changing lanes			
		7	Entering traffic lane (merging)			
		8	Leaving traffic lane			
		9	Backing			
		10	Slowing/stopping			
		11	Stopped for stop sign/signal			
		12	Legally Parked			
		13	Illegally Parked/Unattended			
		14	Other (explain in narrative)			
		77	Not reported.			
		99	Unknown			
VLP_State	License Plate State			Character	2	0
		AL	Alabama			
		AK	Alaska			
		AZ	Arizona			
		AR	Arkansas			
		CA	California			
		CO	Colorado			
		CT	Connecticut			
		DE	Delaware			
		FL	Florida			
		GA	Georgia			
		HI	Hawaii			
		ID	Idaho			
		IL	Illinois			
		IN	Indiana			
		IA	Iowa			
		KS	Kansas			
		KY	Kentucky			
		LA	Louisiana			
		ME	Maine			
		MD	Maryland			
		MA	Massachusetts			
		MI	Michigan			
		MN	Minnesota			
		MS	Mississippi			
		MO	Missouri			
		MT	Montana			
		NE	Nebraska			
		NV	Nevada			
		NH	New Hampshire			
		NJ	New Jersey			
		NM	New Mexico			
		NY	New York			
		NC	North Carolina			
		ND	North Dakota			
		OH	Ohio			
		OK	Oklahoma			
		OR	Oregon			
		PA	Pennsylvania			

		RI	Rhode Island			
		SC	South Carolina			
		SD	South Dakota			
		TN	Tennessee			
		TX	Texas			
		UT	Utah			
		VT	Vermont			
		VA	Virginia			
		WA	Washington			
		DC	Washington DC			
		WV	West Virginia			
		WI	Wisconsin			
		WY	Wyoming			
		XX	Not reported.			
VLP_Year	License Plate Year		License plate year in YYYY format.	Numeric: Integer	4	0
		7777	Not reported.			

Vehicle Damage Parameters (zvdm)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique Identifier		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
V2UnitNum	Vehicle Unit Number		Number indicating which vehicle the driver was operating.	Numeric: Integer	3	0
		777	Not reported.			
V2UnitKey	Combined Crash_Key and V2UnitNum		Crash_Key*1000+V2UnitNum	Numeric: Integer	13	0
InitImpact	Point of Initial Impact			Numeric: Integer	2	0
		1	Front			
		2	Passenger side - front			
		3	Passenger side - middle			
		4	Passenger side - rear			
		5	Rear			
		6	Driver side - rear			
		7	Driver side - middle			
		8	Driver side - front			
		9	Top			
		10	Under-Carriage			
		77	Not reported.			
		99	Unknown			
MostDamage	Most Damaged Area			Numeric: Integer	2	0
		1	Front			
		2	Passenger side - front			
		3	Passenger side - middle			
		4	Passenger side - rear			
		5	Rear			
		6	Driver side - rear			
		7	Driver side - middle			
		8	Driver side - front			
		9	Top			
		10	Under-Carriage			
		77	Not reported.			
		99	Unknown			
Damage	Extent of Damage			Numeric: Integer	2	0
		1	None			
		2	Minor damage			
		3	Functional damage			
		4	Disabling damage			
		5	Severe - vehicle totaled			
		9	Unknown			
		77	Not reported.			
UnderOver	Underride/Override			Numeric: Integer	2	0
		1	None			
		2	Underride - compartment intrusion			
		3	Underride - no compartment intrusion			
		4	Underride - compartment intrusion unknown			
		5	Override - moving vehicle			
		6	Override - parked/stationary vehicle			
		9	Unknown			
		77	Not reported.			
RepairCost	Approximate Cost to Repair or Replace		Estimated dollar value of repairs to vehicle.	Numeric: Integer	9	0

Commercial Vehicle Crash Parameters (zcvo)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
CUnitNum	Commercial Vehicle Unit Number		Number indicating which commercial vehicle.	Numeric: Integer	3	0
		777	Not reported.			
CUnitKey	Combined Crash_Key and CUnitNum		Crash_Key*1000+CUnitNum	Numeric: Integer	13	0
Axles	Number of Axles		Number of axles for the commercial vehicle.	Numeric: Integer	2	0
GVWR	Gross Vehicle Weight Rating		Gross vehicle weight rating (GVWR) for the commercial vehicle.	Numeric: Integer	6	0
Placard	Placard #		The placard number for the hazardous materials being transported.	Numeric: Integer	6	0
		777777	Not reported.			
HazMatRel	Hazardous Materials Released?		Indication of release of hazardous materials.	Character	2	0
		1	Yes			
		2	No			
		3	Not applicable			
		9	Unknown			
		77	Not reported.			
HazMat_PL	HazMat_PL		Indication of a placard.	Numeric: Integer	6	0
		7	Not reported.			
CVLPState1	License Plate State (power unit attached)		State the unit attached to the power unit is licensed in.	Character	2	0
		AL	Alabama			
		AK	Alaska			
		AZ	Arizona			
		AR	Arkansas			
		CA	California			
		CO	Colorado			
		CT	Connecticut			
		DE	Delaware			
		FL	Florida			
		GA	Georgia			
		HI	Hawaii			
		ID	Idaho			
		IL	Illinois			
		IN	Indiana			
		IA	Iowa			
		KS	Kansas			
		KY	Kentucky			
		LA	Louisiana			
		ME	Maine			
		MD	Maryland			
		MA	Massachusetts			
		MI	Michigan			
		MN	Minnesota			
		MS	Mississippi			
		MO	Missouri			
		MT	Montana			
		NE	Nebraska			
		NV	Nevada			
		NH	New Hampshire			
		NJ	New Jersey			
		NM	New Mexico			
		NY	New York			
		NC	North Carolina			
		ND	North Dakota			
		OH	Ohio			
		OK	Oklahoma			
		OR	Oregon			
		PA	Pennsylvania			
		RI	Rhode Island			
		SC	South Carolina			
		SD	South Dakota			
		TN	Tennessee			
		TX	Texas			
		UT	Utah			
		VT	Vermont			
		VA	Virginia			
		WA	Washington			
		DC	Washington DC			
		WV	West Virginia			
		WI	Wisconsin			
		WY	Wyoming			
		XX	Not reported.			
CVLPYear1	License Plate Year (power unit attached)		License year for unit attached to the power unit.	Numeric: Integer	4	0
		7777	Not reported.			
CVLPState2	License Plate State (power unit attached)		State the unit attached to a trailer unit is licensed in.	Character	2	0
			(see CVLPState1 definitions)			
CVLPYear2	License Plate Year (power unit attached)		License year for unit attached to a trailer unit.	Numeric: Integer	4	0
		7777	Not reported.			

Driver Crash Parameters (zdrv)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique Identifier		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
D1UnitNum	Vehicle Unit Number		Number indicating which vehicle the driver was operating.	Numeric: Integer	3	0
		777	Not reported.			
D1UnitKey	Combined Crash_Key and D1UnitNum		Crash_Key*1000+D1UnitNum	Numeric: Integer	13	0
DriverAge	Driver Age		Age of driver derived from Date of Birth and Crash Date.	Numeric: Integer	3	0
DAgeBin1	Driver Ages by primarily 5 year bins		Driver Age field divided into bins by primarily 5 year age ranges.	Numeric: Integer	2	0
		1	DriverAge < 14			
		2	DriverAge = 14			
		3	DriverAge = 15			
		4	DriverAge = 16			
		5	DriverAge = 17			
		6	DriverAge = 18			
		7	DriverAge = 19			
		8	DriverAge = 20			
		9	DriverAge >= 21 and DriverAge <= 24			
		10	DriverAge >= 25 and DriverAge <= 29			
		11	DriverAge >= 30 and DriverAge <= 34			
		12	DriverAge >= 35 and DriverAge <= 39			
		13	DriverAge >= 40 and DriverAge <= 44			
		14	DriverAge >= 45 and DriverAge <= 49			
		15	DriverAge >= 50 and DriverAge <= 54			
		16	DriverAge >= 55 and DriverAge <= 59			
		17	DriverAge >= 60 and DriverAge <= 64			
		18	DriverAge >= 65 and DriverAge <= 69			
		19	DriverAge >= 70 and DriverAge <= 74			
		20	DriverAge >= 75 and DriverAge <= 79			
		21	DriverAge >= 80 and DriverAge <= 84			
		22	DriverAge >= 85 and DriverAge <= 89			
		23	DriverAge >= 90 and DriverAge <= 94			
		24	DriverAge >= 95 and DriverAge <= 98 (actually, 98 is 98 and greater)			
		77	Not reported.			
		99	Unknown			
DriverDOB	Driver Date of Birth		Driver's date of birth in YYYYMMDD format (e.g., 19850316).	Numeric: Integer	8	0
		77777777	Not reported.			
DriverGen	Driver Gender			Character	2	0
		M	Male			
		F	Female			
		U	Unknown			
		NR	Not reported.			
Charged	Driver Charged?			Numeric: Integer	2	0
		1	Yes			
		2	No			
		3	Not applicable.			
		9	Unknown			
		77	Not reported.			
AlcTest	Alcohol Test Administered			Numeric: Integer	1	0
		1	None			
		2	Blood			
		3	Urine			
		4	Breath			
		5	Vitreous			
		9	Refused			
		77	Not reported.			
AlcResult	Alcohol Test Results		Number in decimal format (e.g., 0.10) representing Blood Alcohol Content.	Numeric: Decimal	5	3
DrugTest	Drug Test Administered			Numeric: Integer	2	0
		1	None			
		2	Blood			
		3	Urine			
		9	Refused			
		77	Not reported.			
DrugResult	Drug Test Results			Numeric: Integer	2	0
		1	Positive			
		2	Negative			
		77	Not reported.			
DriverCond	Driver Condition			Numeric: Integer	2	0
		1	Apparently normal			
		2	Physical impairment			
		3	Emotional (e.g. depressed/angry/disturbed)			
		4	Illness			
		5	Asleep/fainted/fatigued/etc.			
		6	Under the influence of alcohol/drugs/medications			
		8	Other (explain in narrative)			
		9	Unknown			
		77	Not reported.			

Driver Crash Parameters (zdrv) – cont.

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
DContCirc1	Contributing Circumstances 1 - Driver			Numeric: Integer	2	0
		1	Ran traffic signal			
		2	Ran stop sign			
		3	Exceeded authorized speed			
		4	Driving too fast for conditions			
		5	Made improper turn			
		6	Traveling wrong way or on wrong side of road			
		7	Crossed centerline			
		8	Lost Control			
		9	Followed too close			
		10	Swerved to avoid: vehicle/object/non-motorist/or animal in roadway			
		11	Over correcting/over steering			
		12	Operating vehicle in an erratic/reckless/careless/negligent/aggressive manner			
		13	FTYROW: From stop sign			
		14	FTYROW: From yield sign			
		15	FTYROW: Making left turn			
		16	FTYROW: Making right turn on red signal			
		17	FTYROW: From driveway			
		18	FTYROW: From parked position			
		19	FTYROW: To pedestrian			
		20	FTYROW: At uncontrolled intersection			
		21	FTYROW: Other (explain in narrative)			
		22	Inattentive/distracted by: Passenger			
		23	Inattentive/distracted by: Use of phone or other device			
		24	Inattentive/distracted by: Fallen object			
		25	Inattentive/distracted by: Fatigued/asleep			
		26	Other (explain in narrative): Vision obstructed			
		27	Other (explain in narrative): Other improper action			
		28	Other (explain in narrative): No improper action			
		77	Not reported.			
		99	Unknown			
DContCirc2	Contributing Circumstances 2 - Driver		See DContCirc1 values.	Numeric: Integer	2	0
VisionObs	Vision Obscurement			Numeric: Integer	2	0
		1	Not obscured			
		2	Trees/crops			
		3	Buildings			
		4	Embankment			
		5	Sign/billboard			
		6	Hillcrest			
		7	Parked vehicles			
		8	Moving vehicles			
		9	Person/object in or on vehicle			
		10	Blinded by sun or headlights			
		11	Frosted windows/windshield			
		12	Blowing snow			
		13	Fog/smoke/dust			
		77	Not reported.			
		88	Other (explain in narrative)			
		99	Unknown			

Driver Crash Parameters (zdrv) – cont.

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
DL_State	Driver's License State			Character	2	0
		AL	Alabama			
		AK	Alaska			
		AZ	Arizona			
		AR	Arkansas			
		CA	California			
		CO	Colorado			
		CT	Connecticut			
		DE	Delaware			
		FL	Florida			
		GA	Georgia			
		HI	Hawaii			
		ID	Idaho			
		IL	Illinois			
		IN	Indiana			
		IA	Iowa			
		KS	Kansas			
		KY	Kentucky			
		LA	Louisiana			
		ME	Maine			
		MD	Maryland			
		MA	Massachusetts			
		MI	Michigan			
		MN	Minnesota			
		MS	Mississippi			
		MO	Missouri			
		MT	Montana			
		NE	Nebraska			
		NV	Nevada			
		NH	New Hampshire			
		NJ	New Jersey			
		NM	New Mexico			
		NY	New York			
		NC	North Carolina			
		ND	North Dakota			
		OH	Ohio			
		OK	Oklahoma			
		OR	Oregon			
		PA	Pennsylvania			
		RI	Rhode Island			
		SC	South Carolina			
		SD	South Dakota			
		TN	Tennessee			
		TX	Texas			
		UT	Utah			
		VT	Vermont			
		VA	Virginia			
		WA	Washington			
		DC	Washington DC			
		WV	West Virginia			
		WI	Wisconsin			
		WY	Wyoming			
		XX	Not reported.			
DLRestComp	Driver's License Restrictions Complied With?		Not currently in crash database.			
		1	Yes			
		2	No			
		7	Not reported.			

Crash Type Parameters 2 (zctb)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
V3UnitNum	Vehicle Unit Number		Number indicating which vehicle.	Numeric: Integer	3	0
		777	Not reported.			
V3UnitKey	Combined Crash_Key and V3UnitNum		Crash_Key*1000+V3UnitNum	Numeric: Integer	13	0
SeqEvents1	Sequence of Events 1st Event			Numeric: Integer	2	0
		1	Ran off road, right			
		2	Ran off road, straight			
		3	Ran off road, left			
		4	Crossed centerline/median			
		5	Animal or object in roadway			
		6	Evasive action (swerve, panic braking, etc.)			
		7	Downhill runaway			
		8	Cargo/equipment loss or shift			
		9	Equipment failure (tires, brakes, etc.)			
		10	Separation of units			
		11	Non-collision events: Overturn/rollover			
		12	Non-collision events: Jackknife			
		13	Non-collision events: Other non-collision (explain in narrative)			
		20	Collision with: Non-motorist (see non-motorist type)			
		21	Collision with: Vehicle in traffic			
		22	Collision with: Vehicle in/from other roadway			
		23	Collision with: Parked motor vehicle			
		24	Collision with: Railway vehicle/train			
		25	Collision with: Animal			
		26	Collision with: Other non-fixed object (explain in narrative)			
		30	Collision with fixed object: Bridge/bridge rail/overpass			
		31	Collision with fixed object: Underpass/structure support			
		32	Collision with fixed object: Culvert			
		33	Collision with fixed object: Ditch/embankment			
		34	Collision with fixed object: Curb/island/raised median			
		35	Collision with fixed object: Guardrail			
		36	Collision with fixed object: Concrete barrier (median or right side)			
		37	Collision with fixed object: Tree			
		38	Collision with fixed object: Poles (utility, light, etc.)			
		39	Collision with fixed object: Sign post			
		40	Collision with fixed object: Mailbox			
		41	Collision with fixed object: Impact attenuator			
		42	Collision with fixed object: Other fixed object (explain in narrative)			
		50	Miscellaneous events: Fire/explosion			
		51	Miscellaneous events: Immersion			
		52	Miscellaneous events: Hit and run			
		77	Not reported			
		99	Unknown			
SeqEvents2	Sequence of Events 2nd Event		See SeqEvents1 values.	Numeric: Integer	2	0
SeqEvents3	Sequence of Events 3rd Event		See SeqEvents1 values.	Numeric: Integer	2	0
SeqEvents4	Sequence of Events 4th Event		See SeqEvents1 values.	Numeric: Integer	2	0
MostHarm	Most Harmful Event		See SeqEvents1 values.	Numeric: Integer	2	0

Roadway Crash Parameters 2 (zrdb)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
RUnitNum	Vehicle Unit Number		Number indicating which vehicle.	Numeric: Integer	3	0
		777	Not reported.			
RUnitKey	Combined Crash_Key and RUnitNum		Crash_Key*1000+RUnitNum	Numeric: Integer	13	0
SpeedLimit	Speed Limit			Numeric: Integer	2	0
		0	0 MPH			
		5	5 MPH			
		10	10 MPH			
		15	15 MPH			
		20	20 MPH			
		25	25 MPH			
		30	30 MPH			
		35	35 MPH			
		40	40 MPH			
		45	45 MPH			
		50	50 MPH			
		55	55 MPH			
		60	60 MPH			
		65	65 MPH			
TrafCont	Traffic Controls			Numeric: Integer	2	0
		1	No controls present			
		2	Traffic signals			
		3	Flashing traffic control signal			
		4	Stop signs			
		5	Yield signs			
		6	No Passing Zone (marked)			
		7	Warning sign			
		8	School zone signs			
		9	Railway crossing device			
		10	Traffic director			
		11	Workzone signs			
		77	Not reported.			
		88	Other control (explain in narrative)			
		99	Unknown			
Trafficway	Type of Trafficway			Numeric: Integer	2	0
		1	One Lane or Ramp			
		2	Two Lanes			
		3	Three Lanes			
		4	Four or More/Undivided			
		5	Four or More/Divided			
		6	Alley			
		7	Driveway			
		8	Other			
		77	Not reported.			
		99	Unknown			
TrfficFlow	Traffic Flow			Numeric: Integer	2	0
		1	One-Way Traffic			
		2	Two-Way Traffic			
		77	Not reported.			
		99	Unknown			
SurfaceTyp	Surface Type			Numeric: Integer	2	0
		1	Cement/Concrete			
		2	Asphalt			
		3	Gravel/Rock			
		4	Dirt			
		5	Brick			
		6	Steel (Bridge Floor)			
		7	Wood (Bridge Floor)			
		8	Other			
		77	Not reported.			
		99	Unknown			

Injury Crash Parameters (zinj)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
IUnitNum	Vehicle Unit Number		Number indicating which vehicle the injured person was in.	Numeric: Integer	3	0
		777	Not reported.			
IUnitKey	Combined Crash_Key and IUnitNum		Crash_Key*1000+IUnitNum	Numeric: Integer	13	0
INumber	Injured Person Number		Number indicating which injured person.	Numeric: Integer	3	0
		777	Not reported.			
INumKey	Combined Crash_Key and INumber		Crash_Key*1000+INumber	Numeric: Integer	13	0
InjStatus	Injury Status/Severity			Numeric: Integer	2	0
		1	Fatal			
		2	Incapacitating			
		3	Non-incapacitating			
		4	Possible			
		5	Uninjured			
		9	Unknown			
		77	Not reported.			
InjuredAge	Age of Injured Person		Age of injured person derived from Date of Birth and Crash Date.	Numeric: Integer	3	0
InjuredDOB	Date of Birth of Injured Person		Driver's date of birth in YYYYMMDD format (e.g., 19850316).	Numeric: Integer	8	0
		77777777	Not reported.			
InjuredGen	Gender of Injured Person			Character	2	0
		M	Male			
		F	Female			
		U	Unknown			
		NR	Not reported.			
Seating	Seating Position			Numeric: Integer	2	0
		1	Driver/Motorcycle Driver			
		2	Front Seat Middle			
		3	Front Seat Passenger Side			
		4	Rear Seat Driver Side/Motorcycle Passenger			
		5	Rear Seat Middle			
		6	Rear Seat Passenger Side			
		7	Third Seat Driver Side			
		8	Third Seat Middle			
		9	Third Seat Passenger Side			
		10	Sleeper Section			
		11	Enclosed Cargo Area			
		12	Unenclosed Cargo Area			
		13	Trailing Unit			
		14	Exterior			
		15	Pedestrian			
		16	Pedalcyclist			
		17	Pedalcyclist passenger			
		77	Not reported.			
		88	Other (explain in narrative)			
		99	Unknown			
OccProtect	Occupant Protection			Numeric: Integer	2	0
		1	None used			
		2	Shoulder and lap belt used			
		3	Lap belt only used			
		4	Shoulder belt only used			
		5	Child safety seat used			
		6	Helmet used			
		8	Other (explain in narrative)			
		9	Unknown			
		77	Not reported.			
Ejection	Ejection			Numeric: Integer	2	0
		1	Not ejected			
		2	Partially ejected			
		3	Totally ejected			
		4	Not applicable (motorcycle/bicycle/etc.)			
		9	Unknown			
		77	Not reported.			
EjectPath	Ejection Path			Numeric: Integer	2	0
		1	Not ejected/not applicable			
		2	Through front windshield			
		3	Through side window/door			
		4	Through roof			
		5	Through back window/tailgate			
		9	Unknown			
		77	Not reported.			

Injury Crash Parameters (zinj) – cont.

AirbagDep	Airbag Deployment			Numeric: Integer	2	0
		1	Deployed front of person			
		2	Deployed side of person			
		3	Deployed both front/side			
		4	Other deployment (explain in narrative)			
		5	Not deployed			
		6	Not applicable			
		9	Unknown			
		77	Not reported.			
AirbagSw	Airbag Switch Status			Numeric: Integer	2	0
		1	Switch in ON position			
		2	Switch in OFF position			
		3	No ON/OFF switch present			
		9	Unknown			
		77	Not reported.			
Trapped	Occupant Trapped?			Numeric: Integer	2	0
		1	Not trapped			
		2	Freed by non-mechanical means			
		3	Extricated by mechanical means			
		9	Unknown			
		77	Not reported.			
TransTo	Transported To:		Medical facility the injured person was transported to.	Character	20	0
TransBy	Transported By:		Medical service the injured person was transported by.	Character	20	0

Non-Motorist Crash Parameters (znmt)

Field Name	Field Description	Values	Values Descriptions	Field Type	Field Width	Field Precision
Crash_Key	Crash Key - SAVER Internal Unique		4 digit year + arbitrarily assigned unique number (e.g., 2001000025)	Numeric: Integer	10	0
NMUnitNum	Unit Number of Vehicle Striking (Vehicle		Number indicating which vehicle struck the non-motorist.	Numeric: Integer	3	0
	Unit Number)	777	Not reported.			
NMUnitKey	Combined Crash_Key and NMUnitNum		Crash_Key*1000+NMUnitNum	Numeric: Integer	13	0
NMNumber	Number of Non-Motorist		Number indicating which non-motorist.	Numeric: Integer	3	0
		777	Not reported.			
NMNumKey	Combined Crash_Key and NMNumber		Crash_Key*1000+NMNumber	Numeric: Integer	13	0
NM_Type	Non-Motorist Type			Numeric: Integer	2	0
		1	Pedestrian			
		2	Pedalcyclist (bicycle/tricycle/unicycle/pedal car)			
		3	Skater			
		8	Other (explain in narrative)			
		9	Unknown			
		77	Not reported.			
NM_Loc	Non-Motorist Location			Numeric: Integer	2	0
		1	Marked crosswalk at intersection			
		2	At intersection - no crosswalk			
		3	Non-intersection crosswalk			
		4	Driveway access crosswalk			
		8	Other non-intersection (explain in narrative)			
		9	Unknown			
		77	Not reported.			
NM_Action	Non-Motorist Action			Numeric: Integer	2	0
		1	Entering or crossing roadway			
		2	Walking/running/jogging/playing/cycling			
		3	Working			
		4	Pushing vehicle			
		5	Approaching or leaving vehicle			
		6	Playing or working on vehicle			
		7	Standing			
		8	Other (explain in narrative)			
		9	Unknown			
		77	Not reported.			
NM_Cond	Non-Motorist Condition			Numeric: Integer	2	0
		1	Apparently normal			
		2	Physical impairment			
		3	Emotional (e.g. depressed/angry/disturbed)			
		4	Illness			
		5	Asleep/fainted/fatigued/etc.			
		6	Under the influence of alcohol/drugs/medications			
		8	Other (explain in narrative)			
		9	Unknown			
		77	Not reported.			
NM_Safety	Non-Motorist Safety Equipment			Numeric: Integer	2	0
		1	Helmet			
		2	Reflective clothing			
		3	Lighting			
		4	None			
		8	Other (explain in narrative)			
		9	Unknown			
		77	Not reported.			
NMContCirc	Contributing Circumstancs - Non-Motorist			Numeric: Integer	2	0
		1	Improper crossing			
		2	Darting			
		3	Lying or sitting in roadway			
		4	Failure to yield right of way			
		5	Not visible (dark clothing)			
		6	Inattentive (talking/eating/etc.)			
		7	Failure to obey traffic signs/signals/officer			
		8	Wrong side of road			
		77	Not reported.			
		88	Other (explain in narrative)			
		99	Unknown			

APPENDIX H. DATABASE QUERY RESULTS & CRASH SEVERITY AND FREQUENCY CALCULATIONS

Severity and Frequency of crashes (total # of crashes)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%
1	8	6	6	7	7	1	5	7	1	47	0.87%
2	9	21	25	34	31	26	28	27	2	201	3.72%
3	44	77	75	72	98	88	56	69	3	579	10.71%
4	74	110	143	151	176	161	111	135	4	1061	19.63%
5	222	331	515	588	527	464	439	431	5	3517	65.07%
total	357	545	764	852	839	740	639	669	total	5405	

query: CSEVERITY VEHNUM = 1

Severity and Frequency of crashes (total # of vehicles involved)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%
1	23	17	9	11	11	2	7	13	1	93	0.90%
2	18	52	39	68	52	46	46	47	2	368	3.55%
3	96	174	130	150	178	166	88	119	3	1101	10.62%
4	157	250	294	306	347	308	210	263	4	2135	20.59%
5	416	663	988	1141	998	908	795	763	5	6672	64.35%
total	710	1156	1460	1676	1586	1430	1146	1205	total	10369	

query: CSEVERITY VEHNUM = 1,2,3,4,5,6,7,8,9

#3) build/rebuild under traffic (#crashes) - work on shoulder

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals
1	1	0	2	2	0	0	2	0	1	7
2	0	2	2	6	3	1	3	3	2	20
3	9	7	9	7	17	8	11	9	3	77
4	19	19	27	36	26	27	15	13	4	182
5	27	42	76	92	84	73	57	48	5	499
									total	785

query: WZ_TYPE=3 VEHNUM = 1
CSEVERITY FATALITIES

#3) build/rebuild under traffic (#crashes) - intermittent or moving work

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals
1	1	0	0	0	1	0	0	2	1	4
2	1	3	1	1	3	0	4	1	2	14
3	3	1	3	4	6	7	5	4	3	33
4	1	8	4	4	6	7	7	8	4	45
5	15	22	20	39	31	21	33	33	5	214
									total	310

query: WZ_TYPE=4 VEHNUM = 1
CSEVERITY FATALITIES

1 #3) build/rebuild under traffic (#vehicles) - work on shoulder

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	3	0	3	3	0	0	3	0	1	12	0.79%	0.9	0.8
2	0	6	4	8	6	2	4	5	2	35	2.31%	0.7	
3	22	10	13	15	29	27	16	13	3	145	9.58%	0.9	
4	38	50	45	74	47	47	26	24	4	351	23.18%	1.1	1.0
5	57	83	148	183	169	140	99	92	5	971	64.13%	1.0	
									total	1514			

query: WZ_TYPE=3 VEHNUM = 1,2,3,4,5,6,7,8,9
CSEVERITY FATALITIES

Frequency Ratio: 0.15

2 #3) build/rebuild under traffic (#vehicles) - intermittent or moving work

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	2	0	0	0	1	0	0	4	1	7	1.25%	1.4	1.3
2	2	6	2	1	4	0	5	2	2	22	3.94%	1.1	
3	8	2	4	7	14	11	8	11	3	65	11.63%	1.1	
4	2	16	8	8	13	17	14	14	4	92	16.46%	0.8	1.0
5	27	43	32	72	53	42	49	55	5	373	66.73%	1.0	

query: WZ_TYPE=4 VEHNUM = 1,2,3,4,5,6,7,8,9 total 559
CSEVERITY FATALITIES Frequency Ratio: 0.05

3 #4) construction vehicle traffic (#vehicles) - dump trucks

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	1	0	0	1	1	1	0	0	1	4	2.17%	2.4	2.1
2	0	3	0	1	3	2	2	1	2	12	6.52%	1.8	
3	0	5	5	4	8	4	5	1	3	32	17.39%	1.6	
4	0	3	2	4	4	1	5	1	4	20	10.87%	0.5	1.0
5	17	14	12	16	16	11	13	17	5	116	63.04%	1.0	

query: CARGOBODY=3 VEHNUM = 1,2,3,4,5,6,7,8,9 total 184
RCONTCIRC = 5 CSEVERITY Frequency Ratio: 0.02

4 #4) construction vehicle traffic (#vehicles) - flatbed

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	1	1	0	0	0	0	0	1	1	3	3.19%	3.6	2.8
2	0	1	1	0	3	0	1	1	2	7	7.45%	2.1	
3	2	0	0	4	2	1	0	0	3	9	9.57%	0.9	
4	1	3	4	2	1	1	1	0	4	13	13.83%	0.7	0.9
5	6	3	9	11	17	3	9	4	5	62	65.96%	1.0	

query: CARGOBODY=5 VEHNUM = 1,2,3,4,5,6,7,8,9 total 94
RCONTCIRC = 5 CSEVERITY Frequency Ratio: 0.01

5 #4) construction vehicle traffic (#vehicles) - concrete mixer

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	0	0	0	0	0	0	0	1	0	0.00%	0.0	0.0
2	0	0	0	0	0	0	0	0	2	0	0.00%	0.0	
3	0	0	1	0	0	1	1	0	3	3	13.64%	1.3	
4	1	1	0	1	1	0	0	0	4	4	18.18%	0.9	1.1
5	2	0	1	3	3	1	2	3	5	15	68.18%	1.1	

query: CARGOBODY=6 VEHNUM = 1,2,3,4,5,6,7,8,9 total 22
RCONTCIRC = 5 CSEVERITY Frequency Ratio: 0.002

6 #7) dirty/non-serviceable signs - traffic control device inoperative/missing/obscured

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	0	0	0	0	0	0	0	1	0	0.00%	0.0	0.7
2	0	1	0	0	0	0	0	0	2	1	4.76%	1.3	
3	0	0	0	0	0	0	0	0	3	0	0.00%	0.0	
4	0	0	0	0	0	2	2	5	4	9	42.86%	2.1	1.0
5	1	0	0	1	5	3	0	1	5	11	52.38%	0.8	

query: RCONTCIRC=8 VEHNUM = 1,2,3,4,5,6,7,8,9 total 21
CSEVERITY Frequency Ratio: 0.002

7 #8) driver/operator inattention

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	0	0	0	0	0	0	0	1	0	0.00%	0.0	1.7
2	1	2	8	2	3	1	0	3	2	20	11.83%	3.3	
3	1	0	0	1	4	3	3	2	3	14	8.28%	0.8	
4	4	4	7	7	10	4	3	7	4	46	27.22%	1.3	1.0
5	10	3	19	9	18	13	10	7	5	89	52.66%	0.8	
									total	169			

query: DCONTCIRC1=22,23,24,25 VEHNUM=1,2,3,4,5,6,7,8,9
DCONTCIRC2=22,23,24,25 CSEVERITY

Frequency Ratio: 0.02

8 #9) driver/operator unfamiliarity (Iowa DL)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	12	10	7	10	10	2	5	4	1	60	0.71%	0.8	0.9
2	18	36	33	49	41	39	34	36	2	286	3.40%	1.0	
3	80	138	110	114	148	143	70	87	3	890	10.60%	1.0	
4	136	194	243	260	302	232	180	218	4	1765	21.01%	1.0	1.0
5	350	531	777	950	848	790	603	550	5	5399	64.27%	1.0	
									total	8400			

query: DL_STATE=IA VEHNUM=1,2,3,4,5,6,7,8,9
CSEVERITY

Frequency Ratio: 0.81

9 #9) driver/operator unfamiliarity (out-of-state driver license)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	11	7	2	1	1	0	2	9	1	33	1.68%	1.9	1.5
2	0	16	6	19	11	7	12	11	2	82	4.16%	1.2	
3	16	36	20	36	30	23	18	32	3	211	10.72%	1.0	
4	21	56	51	46	45	76	30	45	4	370	18.79%	0.9	1.0
5	66	132	211	191	150	118	192	213	5	1273	64.65%	1.0	
									total	1969			

query: DL_STATE=out of state VEHNUM=1,2,3,4,5,6,7,8,9
CSEVERITY

Frequency Ratio: 0.19

10 #9) inadequate/confusing traffic control (no controls present)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	12	8	6	4	3	0	2	4	1	39	0.80%	0.9	0.9
2	3	24	20	34	25	19	15	21	2	161	3.32%	0.9	
3	49	73	67	59	88	74	28	54	3	492	10.13%	1.0	
4	67	121	113	154	169	172	99	100	4	995	20.49%	1.0	1.0
5	173	297	461	616	518	407	372	325	5	3169	65.26%	1.0	
									total	4856			

query: TRAFCONT=1,99 VEHNUM=1,2,3,4,5,6,7,8,9
CSEVERITY

Frequency Ratio: 0.47

11 #11) falling debris/material (fallen object)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	0	0	0	0	0	0	0	1	0	0.00%	0.0	2.1
2	1	0	0	1	2	0	0	1	2	5	15.15%	4.3	
3	0	0	0	0	1	0	0	1	3	2	6.06%	0.6	
4	2	1	1	4	3	0	0	2	4	13	39.39%	1.9	1.0
5	1	0	3	2	4	1	2	0	5	13	39.39%	0.6	
									total	33			

query: DCONTCIRC1=24 VEHNUM=1,2,3,4,5,6,7,8,9
DCONTCIRC2=24 CSEVERITY

Frequency Ratio: 0.003

12 #13) inadequate buffer distance (crashes within or adjacent to work activity)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	2	2	4	4	1	2	4	6	1	25	0.58%	0.6	0.8
2	4	26	18	13	32	15	21	27	2	156	3.59%	1.0	
3	54	45	50	58	97	56	46	59	3	465	10.71%	1.0	
4	56	110	122	134	127	134	89	135	4	907	20.89%	1.0	1.0
5	162	254	370	467	412	385	383	356	5	2789	64.23%	1.0	

query: WZ_LOC=4 VEHNUM=1,2,3,4,5,6,7,8,9 CSEVERITY

total 4342

Frequency Ratio: 0.42

13 #16) inclement weather

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	5	0	2	0	2	0	0	0	1	9	0.97%	1.1	1.2
2	4	10	2	10	2	7	2	5	2	42	4.55%	1.3	
3	13	11	16	28	8	28	7	8	3	119	12.88%	1.2	
4	15	19	31	42	30	24	7	16	4	184	19.91%	1.0	1.0
5	28	50	83	110	69	76	79	75	5	570	61.69%	1.0	

query: WEATHER1=4,5,6,7,8 WEATHER2=4,5,6,7,8 VEHNUM=1,2,3,4,5,6,7,8,9 CSEVERITY

total 924

Frequency Ratio: 0.09

14 #17) increased demand, inadequate capacity/geometry & confusing layout of: (lane closures)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	2	13	4	0	5	0	1	6	1	31	0.65%	0.7	0.9
2	11	17	16	42	20	21	23	22	2	172	3.63%	1.0	
3	43	109	55	70	63	64	41	58	3	503	10.61%	1.0	
4	71	111	141	124	160	140	113	150	4	1010	21.31%	1.0	1.0
5	173	299	439	511	417	433	359	392	5	3023	63.79%	1.0	

query: WZ_TYPE=1 VEHNUM=1,2,3,4,5,6,7,8,9 CSEVERITY

total 4739

Frequency Ratio: 0.46

15 #17) increased demand, inadequate capacity/geometry & confusing layout of: (lane shift/crossover)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	14	2	2	0	2	2	0	0	1	22	1.82%	2.0	1.6
2	0	9	3	7	2	9	10	13	2	53	4.38%	1.2	
3	9	21	17	22	21	21	9	15	3	135	11.17%	1.1	
4	22	19	32	29	40	31	14	28	4	215	17.78%	0.9	1.0
5	63	81	122	113	140	92	99	74	5	784	64.85%	1.0	

query: WZ_TYPE=2 VEHNUM=1,2,3,4,5,6,7,8,9 CSEVERITY

total 1209

Frequency Ratio: 0.12

16 #18) increased number of commercial trucks

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	5	2	2	2	5	1	2	4	1	23	2.26%	2.5	2.1
2	0	13	7	5	9	8	6	12	2	60	5.91%	1.7	
3	7	14	16	16	22	17	8	14	3	114	11.22%	1.1	
4	13	27	25	13	20	20	14	9	4	141	13.88%	0.7	0.9
5	48	67	99	99	91	72	97	105	5	678	66.73%	1.0	

query: VCONFIG=5,6,7,8,9,10,11,12 VEHNUM=1,2,3,4,5,6,7,8,9 CSEVERITY

total 1016

Frequency Ratio: 0.10

17 #24) lack of visibility/glare/lighting (blinded by sun or headlights)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	1	0	0	0	0	0	0	0	1	1	1.61%	1.8	1.8
2	1	1	0	2	0	0	0	0	2	4	6.45%	1.8	
3	0	1	4	3	0	2	0	0	3	10	16.13%	1.5	
4	2	1	1	2	4	2	2	0	4	14	22.58%	1.1	1.1
5	4	1	7	3	2	4	9	3	5	33	53.23%	0.8	

query: VISIONOBS=10 VEHNUM = 1,2,3,4,5,6,7,8,9 total 62

CSEVERITY Frequency Ratio: 0.01

18 #24) lack of visibility/glare/lighting (dark-roadway lighted)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	2	0	0	3	0	0	2	5	1	12	1.33%	1.5	1.1
2	1	3	2	8	1	5	1	4	2	25	2.77%	0.8	
3	5	12	8	17	16	15	5	14	3	92	10.21%	1.0	
4	14	14	23	25	35	28	14	27	4	180	19.98%	1.0	1.0
5	46	72	91	104	98	65	46	70	5	592	65.70%	1.0	

query: LIGHT=4 VEHNUM = 1,2,3,4,5,6,7,8,9 total 901

CSEVERITY Frequency Ratio: 0.09

19 #24) lack of visibility/glare/lighting (dark-roadway not lighted)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	5	0	5	0	2	2	5	0	1	19	3.30%	3.7	2.8
2	0	16	5	4	2	6	0	6	2	39	6.77%	1.9	
3	5	21	12	9	16	19	5	8	3	95	16.49%	1.6	
4	11	13	11	21	19	14	11	10	4	110	19.10%	0.9	1.1
5	17	33	47	76	55	29	17	39	5	313	54.34%	0.8	

query: LIGHT=5 VEHNUM = 1,2,3,4,5,6,7,8,9 total 576

CSEVERITY Frequency Ratio: 0.06

20 #28) poor driver skills (operator error)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	4	3	4	1	3	1	1	3	1	20	0.78%	0.9	1.0
2	7	9	12	20	14	11	13	19	2	105	4.09%	1.2	
3	31	45	39	39	40	45	28	29	3	296	11.53%	1.1	
4	50	69	72	86	84	77	49	58	4	545	21.22%	1.0	1.0
5	86	157	238	285	225	239	199	173	5	1602	62.38%	1.0	

query: DCONTCIRC1 =1,2,4,5,6,7,8,9,11 VEHNUM = 1,2,3,4,5,6,7,8,9 total 2568

CSEVERITY Frequency Ratio: 0.25

21 #28) poor driver skills (aggressive driving)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	1	1	2	2	0	0	0	0	1	6	2.78%	3.1	2.4
2	1	1	0	5	2	1	1	2	2	13	6.02%	1.7	
3	3	4	4	4	9	4	6	3	3	37	17.13%	1.6	
4	3	9	2	5	8	4	2	3	4	36	16.67%	0.8	1.1
5	10	15	15	20	17	15	14	18	5	124	57.41%	0.9	

query: DCONTCIRC1 =12 VEHNUM = 1,2,3,4,5,6,7,8,9 total 216

CSEVERITY Frequency Ratio: 0.02

22 #29) poor visibility of workers (#veh involved in crash w/ worker)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	7	0	0	0	1	0	0	0	1	8	20.00%	22.3	14.7
2	1	1	1	1	2	1	2	1	2	10	25.00%	7.0	
3	1	1	2	2	2	1	0	2	3	11	27.50%	2.6	
4	4	1	0	1	2	1	1	0	4	10	25.00%	1.2	1.3
5	0	0	0	0	0	1	0	0	5	1	2.50%	0.0	

query: NM_ACTION =3 VEHNUM = 1,2,3,4,5,6,7,8,9 total 40

NM_SAFETY = CSEVERITY no reflective Frequency Ratio: 0.004

23 #31) railroads, **pedestrian/bike travel routes & crossings

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	2	0	0	0	0	0	0	1	2	5.56%	6.2	3.1
2	0	0	0	0	0	0	0	0	2	0	0.00%	0.0	
3	0	0	1	0	3	0	0	0	3	4	11.11%	1.0	
4	3	0	3	0	1	0	1	0	4	8	22.22%	1.1	1.0
5	1	9	1	3	0	2	6	0	5	22	61.11%	0.9	

query: ROADTYPE =3 VEHNUM = 1,2,3,4,5,6,7,8,9 total 36

ROADTYPE =21** CSEVERITY Frequency Ratio: 0.003

**There were no crashes involving pedestrian/bike path intersections

24 #32) road characteristics through the workzone (intersections)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	4	0	2	2	6	0	4	0	1	18	0.79%	0.9	0.8
2	3	9	9	9	10	9	7	6	2	62	2.72%	0.8	
3	17	22	25	44	32	32	23	20	3	215	9.43%	0.9	
4	34	47	73	61	73	68	52	62	4	470	20.62%	1.0	1.0
5	132	156	204	273	232	191	162	164	5	1514	66.43%	1.0	

query: ROADTYPE =11,12,13,14,15 VEHNUM = 1,2,3,4,5,6,7,8,9 total 2279

CSEVERITY Frequency Ratio: 0.22

25 #32) road characteristics through the workzone (ramps)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	2	0	1	4	0	0	1	4	1	12	1.08%	1.2	1.2
2	0	3	9	16	2	3	12	2	2	47	4.22%	1.2	
3	0	11	23	6	20	19	8	7	3	94	8.44%	0.8	
4	14	26	30	41	34	38	18	14	4	215	19.30%	0.9	0.9
5	37	44	173	123	122	109	64	74	5	746	66.97%	1.0	

query: ROADTYPE =16,17,18,19,20 VEHNUM = 1,2,3,4,5,6,7,8,9 total 1114

CSEVERITY Frequency Ratio: 0.11

26 #32) road characteristics through the workzone (blind spot/obscurement)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	0	0	0	0	0	0	0	1	0	0.00%	0.0	0.3
2	2	0	2	2	0	0	0	1	2	7	2.18%	0.6	
3	1	5	1	5	6	5	5	5	3	33	10.28%	1.0	
4	9	12	11	11	7	9	2	9	4	70	21.81%	1.1	1.0
5	18	25	37	44	27	19	25	16	5	211	65.73%	1.0	

query: VISIONOBS =2,3,4,5,6,7,8 VEHNUM = 1,2,3,4,5,6,7,8,9 total 321

CSEVERITY Frequency Ratio: 0.03

27 #32) road characteristics through the workzone (bridge/overpass/underpass)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	4	0	0	2	0	0	1	1	7	0.75%	0.8	0.9
2	1	8	6	1	1	3	8	1	2	29	3.10%	0.9	
3	24	25	19	12	10	11	2	15	3	118	12.62%	1.2	
4	19	24	37	17	34	31	11	34	4	207	22.14%	1.1	1.1
5	31	40	140	103	54	61	72	73	5	574	61.39%	1.0	

query: ROADTYPE =2 VEHNUM = 1,2,3,4,5,6,7,8,9 total 935

CSEVERITY Frequency Ratio: 0.09

28 #32) road characteristics through the workzone (shoulders - none/low/soft/high)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	0	0	0	0	0	0	0	1	0	0.00%	0.0	0.0
2	0	0	0	0	0	0	0	0	2	0	0.00%	0.0	
3	0	2	0	0	0	0	0	0	3	2	16.67%	1.6	
4	1	0	0	0	1	2	1	1	4	6	50.00%	2.4	1.5
5	1	0	0	0	3	0	0	0	5	4	33.33%	0.5	
									total	12			

query: RCONTCIRC=9 VEHNUM = 1,2,3,4,5,6,7,8,9 CSEVERITY

Frequency Ratio: 0.001

29 #33) the condition of roadway (road surface condition/debris /ruts/holes/bumps/worn surface)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	2	0	0	0	0	0	1	0	1	3	1.54%	1.7	1.1
2	0	0	0	0	3	0	0	0	2	3	1.54%	0.4	
3	1	2	0	2	2	10	3	3	3	23	11.79%	1.1	
4	3	5	0	0	15	7	12	4	4	46	23.59%	1.1	1.1
5	10	14	2	4	28	20	32	10	5	120	61.54%	1.0	
									total	195			

query: RCONTCIRC=2,3,4,6 VEHNUM = 1,2,3,4,5,6,7,8,9 CSEVERITY

Frequency Ratio: 0.02

30 #34) the points of merge (between advance warning & work area; within transition area for lane shift)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	8	9	2	3	4	0	0	3	1	29	0.87%	1.0	1.0
2	10	22	9	38	9	21	11	12	2	132	3.96%	1.1	
3	21	83	52	60	46	68	22	39	3	391	11.74%	1.1	
4	46	70	89	96	130	81	74	69	4	655	19.67%	1.0	1.0
5	133	226	347	370	305	290	220	232	5	2123	63.75%	1.0	
									total	3330			

query: WZ_LOC=2,3 VEHNUM = 1,2,3,4,5,6,7,8,9 CSEVERITY

Frequency Ratio: 0.32

31 #35) the posted speed through the workzone (65 mph)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	5	9	2	0	2	0	0	0	1	18	2.83%	3.2	2.7
2	3	16	3	15	4	3	4	2	2	50	7.87%	2.2	
3	7	34	7	11	18	3	0	3	3	83	13.07%	1.2	
4	10	21	22	12	27	11	9	2	4	114	17.95%	0.9	1.0
5	11	77	84	59	49	37	30	23	5	370	58.27%	0.9	
									total	635			

query: SPEEDLIMIT=65 VEHNUM = 1,2,3,4,5,6,7,8,9 CSEVERITY

Frequency Ratio: 0.06

32 #35) the posted speed through the workzone (55-60 mph)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	10	2	6	9	8	2	5	6	1	48	1.27%	1.4	1.4
2	9	25	22	42	30	25	27	19	2	199	5.25%	1.5	
3	21	82	63	76	96	75	38	39	3	490	12.92%	1.2	
4	46	106	107	130	123	111	61	57	4	741	19.54%	0.9	1.0
5	132	230	388	442	368	336	236	182	5	2314	61.02%	0.9	
									total	3792			

query: SPEEDLIMIT=60,55 VEHNUM = 1,2,3,4,5,6,7,8,9 CSEVERITY

Frequency Ratio: 0.37

33 #35) the posted speed through the workzone (40-50 mph)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	1	1	0	0	0	0	0	1	1	3	0.20%	0.2	0.5
2	4	2	6	6	4	9	6	9	2	46	3.10%	0.9	
3	18	9	18	13	14	42	21	24	3	159	10.70%	1.0	
4	22	30	46	50	73	61	30	64	4	376	25.30%	1.2	1.1
5	46	77	142	151	139	130	118	99	5	902	60.70%	0.9	

query: SPEEDLIMIT=50,45,40 VEHNUM=1,2,3,4,5,6,7,8,9 CSEVERITY

total 1486

Frequency Ratio: 0.14

34 #35) the posted speed through the workzone (30-35 mph)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	4	1	2	1	0	1	1	1	10	0.37%	0.4	0.5
2	1	5	5	13	10	5	8	9	2	56	2.05%	0.6	
3	34	37	30	38	36	23	14	36	3	248	9.09%	0.9	
4	62	64	84	68	81	85	75	102	4	621	22.76%	1.1	1.0
5	137	141	218	324	270	253	224	226	5	1793	65.73%	1.0	

query: SPEEDLIMIT=35,30 VEHNUM=1,2,3,4,5,6,7,8,9 CSEVERITY

total 2728

Frequency Ratio: 0.26

35 #35) the posted speed through the workzone (< 25 mph)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	7	1	0	0	0	0	0	0	1	8	0.56%	0.6	0.5
2	1	3	3	2	1	2	0	4	2	16	1.11%	0.3	
3	11	10	18	13	14	19	10	14	3	109	7.57%	0.7	
4	12	20	38	37	32	30	30	36	4	235	16.32%	0.8	0.9
5	71	119	172	141	148	129	145	147	5	1072	74.44%	1.2	

query: SPEEDLIMIT=25,20,15,10,5 VEHNUM=1,2,3,4,5,6,7,8,9 CSEVERITY

total 1440

Frequency Ratio: 0.14

36 #38) traffic congestion & delay through the workzone (evasive action)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	2	2	0	0	0	0	0	1	1	5	0.68%	0.8	1.1
2	1	5	7	8	4	4	7	2	2	38	5.21%	1.5	
3	7	14	11	16	18	9	14	4	3	93	12.74%	1.2	
4	17	20	18	18	21	18	11	8	4	131	17.95%	0.9	1.0
5	30	59	68	74	81	64	52	35	5	463	63.42%	1.0	

query: SEQEVENTS1=6 DCONTCIRC1=10 VEHNUM=1,2,3,4,5,6,7,8,9 CSEVERITY

total 730

Frequency Ratio: 0.07

37 #39) traffic speed & speeding (exceeded authorized speed)

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	0	0	2	0	0	0	0	1	2	3.03%	3.4	2.8
2	0	0	1	2	1	0	1	0	2	5	7.58%	2.1	
3	4	1	0	0	3	2	3	2	3	15	22.73%	2.1	
4	1	1	3	0	3	2	1	0	4	11	16.67%	0.8	1.2
5	3	4	3	2	6	0	7	8	5	33	50.00%	0.8	

query: DCONTCIRC1=3 VEHNUM=1,2,3,4,5,6,7,8,9 CSEVERITY

total 66

Frequency Ratio: 0.01

38 #12) high risk traffic - Sundays

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	3	0	0	1	0	0	0	3	1	7	1.04%	1.2	1.4
2	2	12	3	10	3	1	5	1	2	37	5.51%	1.6	
3	9	24	15	13	6	17	11	9	3	104	15.50%	1.5	
4	13	15	16	25	19	23	14	14	4	139	20.72%	1.0	1.1
5	19	34	79	59	62	40	35	56	5	384	57.23%	0.9	
									total	671			

query: DAY=1 CSEVERITY VEHNUM = 1,2,3,4,5,6,7,8,9

Frequency Ratio: 0.06

39 #12) high risk traffic - Mondays

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	0	3	0	0	0	0	3	1	6	0.38%	0.4	0.5
2	0	0	1	4	11	11	3	6	2	36	2.29%	0.6	
3	7	21	15	33	30	27	12	17	3	162	10.31%	1.0	
4	52	25	67	46	66	34	28	26	4	344	21.88%	1.1	1.0
5	76	98	147	151	158	147	129	118	5	1024	65.14%	1.0	
									total	1572			

query: DAY=2 CSEVERITY VEHNUM = 1,2,3,4,5,6,7,8,9

Frequency Ratio: 0.15

40 #12) high risk traffic - Tuesdays

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	6	0	2	0	0	0	0	0	1	8	0.47%	0.5	0.8
2	6	10	14	5	6	3	13	12	2	69	4.04%	1.1	
3	17	19	20	34	32	21	14	16	3	173	10.14%	1.0	
4	13	45	43	46	44	45	26	49	4	311	18.23%	0.9	1.0
5	91	94	153	192	184	163	143	125	5	1145	67.12%	1.0	
									total	1706			

query: DAY=3 CSEVERITY VEHNUM = 1,2,3,4,5,6,7,8,9

Frequency Ratio: 0.16

41 #12) high risk traffic - Wednesdays

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	7	0	1	1	2	0	4	0	1	15	0.85%	0.9	0.9
2	0	7	6	5	8	12	12	10	2	60	3.38%	1.0	
3	21	23	31	14	29	33	12	27	3	190	10.72%	1.0	
4	21	32	50	51	58	71	35	67	4	385	21.71%	1.1	1.0
5	71	115	162	204	191	134	138	108	5	1123	63.34%	1.0	
									total	1773			

query: DAY=4 CSEVERITY VEHNUM = 1,2,3,4,5,6,7,8,9

Frequency Ratio: 0.17

42 #12) high risk traffic - Thursdays

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	2	7	0	4	4	0	0	4	1	21	1.15%	1.3	1.0
2	7	6	8	9	7	2	3	6	2	48	2.64%	0.7	
3	14	37	11	20	31	32	15	11	3	171	9.40%	0.9	
4	27	46	41	50	60	46	40	31	4	341	18.75%	0.9	1.0
5	71	136	170	244	161	185	148	123	5	1238	68.06%	1.1	
query:	DAY=5	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	1819			

Frequency Ratio: 0.18

43 #12) high risk traffic - Fridays

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	4	8	2	3	4	0	1	0	1	22	1.19%	1.3	1.2
2	1	6	5	20	15	11	5	11	2	74	4.02%	1.1	
3	21	29	29	20	41	33	16	26	3	215	11.67%	1.1	
4	19	58	34	55	78	63	43	47	4	397	21.54%	1.0	1.0
5	58	110	172	201	139	167	148	140	5	1135	61.58%	1.0	
query:	DAY=6	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	1843			

Frequency Ratio: 0.18

44 #12) high risk traffic - Saturdays

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	1	2	1	2	1	2	2	3	1	14	1.43%	1.6	1.4
2	2	9	2	15	2	4	5	1	2	40	4.08%	1.1	
3	7	21	9	16	9	3	8	13	3	86	8.77%	0.8	
4	12	29	43	33	22	26	24	29	4	218	22.22%	1.1	1.0
5	30	76	105	90	103	72	54	93	5	623	63.51%	1.0	
query:	DAY=7	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	981			

Frequency Ratio: 0.09

45 #10) seasonal road use - January

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	2	0	0	0	0	0	0	0	1	2	1.06%	1.2	0.9
2	0	4	0	0	0	0	0	0	2	4	2.12%	0.6	
3	0	0	0	3	7	10	1	0	3	21	11.11%	1.0	
4	2	1	5	2	6	0	11	1	4	28	14.81%	0.7	1.0
5	5	13	14	18	26	25	27	6	5	134	70.90%	1.1	
query:	MONTH=1	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	189			
									Frequency Ratio:	0.02			

46 #10) seasonal road use - February

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	0	2	0	0	0	0	0	1	2	0.98%	1.1	0.7
2	0	0	0	2	0	0	0	0	2	2	0.98%	0.3	
3	0	0	8	0	0	0	4	0	3	12	5.88%	0.6	
4	0	3	6	4	15	2	7	6	4	43	21.08%	1.0	0.9
5	6	3	25	20	25	25	23	18	5	145	71.08%	1.1	
query:	MONTH=2	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	204			
									Frequency Ratio:	0.02			

47 #10) seasonal road use - March

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	0	0	0	0	0	0	0	1	0	0.00%	0.0	0.5
2	1	0	2	3	0	2	0	2	2	10	3.80%	1.1	
3	0	1	4	10	6	3	4	3	3	31	11.79%	1.1	
4	1	7	4	12	2	5	7	7	4	45	17.11%	0.8	1.0
5	4	16	19	35	41	22	21	19	5	177	67.30%	1.0	
query:	MONTH=3	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	263			
									Frequency Ratio:	0.03			

48 #10) seasonal road use - April

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	0	0	2	0	0	0	0	1	2	0.26%	0.3	1.0
2	0	12	7	7	3	4	8	3	2	44	5.76%	1.6	
3	4	9	7	22	9	5	8	3	3	67	8.77%	0.8	
4	3	12	18	32	14	34	12	10	4	135	17.67%	0.9	0.9
5	20	56	80	81	85	90	66	38	5	516	67.54%	1.0	
query:	MONTH=4	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	764			
									Frequency Ratio:	0.07			

49 #10) seasonal road use - May

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	2	1	0	0	0	0	3	1	6	0.56%	0.6	0.8
2	6	0	1	5	12	6	2	3	2	35	3.27%	0.9	
3	16	20	20	7	25	14	7	4	3	113	10.57%	1.0	
4	5	35	27	26	25	36	18	36	4	208	19.46%	0.9	1.0
5	41	58	107	114	115	122	74	76	5	707	66.14%	1.0	
query:	MONTH=5	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	1069			
									Frequency Ratio:	0.10			

50 #10) seasonal road use - June

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	7	7	3	2	3	0	0	0	1	22	1.66%	1.9	1.5
2	7	10	2	7	7	7	12	2	2	54	4.08%	1.1	
3	13	34	27	13	18	14	12	12	3	143	10.80%	1.0	
4	29	23	54	34	48	31	35	24	4	278	21.00%	1.0	1.0
5	45	80	156	174	107	93	90	82	5	827	62.46%	1.0	
query:	MONTH=6	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	1324			
									Frequency Ratio:	0.13			

51 #10) seasonal road use - July

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	2	0	3	0	2	1	1	1	9	0.64%	0.7	0.9
2	0	6	7	11	9	5	7	12	2	57	4.08%	1.2	
3	17	40	15	25	24	7	15	15	3	158	11.32%	1.1	
4	20	30	55	51	45	41	24	21	4	287	20.56%	1.0	1.0
5	73	99	144	151	115	104	99	100	5	885	63.40%	1.0	
query:	MONTH=7	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	1396			

Frequency Ratio: 0.13

52 #10) seasonal road use - August

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	2	1	0	0	0	2	3	1	8	0.57%	0.6	0.7
2	0	2	9	4	4	6	1	8	2	34	2.42%	0.7	
3	15	33	9	18	29	27	8	23	3	162	11.51%	1.1	
4	18	41	53	33	36	31	33	43	4	288	20.47%	1.0	1.0
5	52	97	140	125	141	110	131	119	5	915	65.03%	1.0	
query:	MONTH=8	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	1407			

Frequency Ratio: 0.14

53 #10) seasonal road use - September

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	12	0	2	0	4	0	0	6	1	24	1.63%	1.8	1.5
2	0	10	4	10	5	11	11	10	2	61	4.14%	1.2	
3	6	18	30	14	21	32	9	23	3	153	10.38%	1.0	
4	23	55	25	33	53	55	33	46	4	323	21.91%	1.1	1.0
5	68	79	130	156	131	104	94	151	5	913	61.94%	1.0	
query:	MONTH=9	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	1474			

Frequency Ratio: 0.14

54 #10) seasonal road use - October

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	0	0	4	2	0	0	0	1	6	0.47%	0.5	0.7
2	2	0	3	12	7	3	2	7	2	36	2.81%	0.8	
3	8	12	8	12	28	30	10	28	3	136	10.61%	1.0	
4	29	29	23	56	62	32	19	44	4	294	22.93%	1.1	1.0
5	53	91	96	113	117	126	107	107	5	810	63.18%	1.0	
query:	MONTH=10	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	1282			

Frequency Ratio: 0.12

55 #10) seasonal road use - November

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	2	4	0	0	2	0	4	0	1	12	1.60%	1.8	1.2
2	2	2	2	3	3	2	0	0	2	14	1.87%	0.5	
3	14	6	2	16	10	15	9	8	3	80	10.68%	1.0	
4	21	13	18	17	29	31	6	25	4	160	21.36%	1.0	1.0
5	42	45	58	107	60	73	53	45	5	483	64.49%	1.0	
query:	MONTH=11	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	749			

Frequency Ratio: 0.07

56 #10) seasonal road use - December

Severity	2001	2002	2003	2004	2005	2006	2007	2008	Severity	totals	%	SEVERITY RATIO	AVG SEVERITY RATIO
1	0	0	0	0	0	0	0	0	1	0	0.00%	0.0	1.0
2	0	6	2	4	2	0	3	0	2	17	6.80%	1.9	
3	3	1	0	10	1	9	1	0	3	25	10.00%	0.9	
4	6	1	6	6	12	10	5	0	4	46	18.40%	0.9	0.9
5	7	26	19	47	35	16	10	2	5	162	64.80%	1.0	
query:	MONTH=12	CSEVERITY		VEHNUM = 1,2,3,4,5,6,7,8,9					total	250			

Frequency Ratio: 0.02

APPENDIX I. FREQUENCY OF CRASH SEVERITY AND CRASH FREQUENCY OBSERVATIONS

AVG SEVERITY RATIO (SR^{avg})	$Log_{10}(SR^{avg})$	Frequency of Observation
0.001	-3.00	2
0.3	-0.50	1
0.5	-0.30	5
0.7	-0.15	4
0.8	-0.10	5
0.9	-0.05	7
1	0.00	5
1.1	0.04	3
1.2	0.08	4
1.3	0.11	1
1.4	0.15	3
1.5	0.18	3
1.6	0.20	1
1.7	0.23	1
1.8	0.26	1
2.1	0.32	3
2.4	0.38	1
2.7	0.43	1
2.8	0.45	3
3.1	0.49	1
14.7	1.17	1

Relative Frequency (RF)	$Log_{10}(RF)$	Frequency of Observation
0.001	-3.00	1
0.002	-2.70	2
0.003	-2.52	2
0.004	-2.40	1
0.01	-2.00	3
0.02	-1.70	7
0.03	-1.52	2
0.05	-1.30	1
0.06	-1.22	3
0.07	-1.15	3
0.09	-1.05	4
0.1	-1.00	2
0.11	-0.96	1
0.12	-0.92	2
0.13	-0.89	2
0.14	-0.85	4
0.15	-0.82	2
0.16	-0.80	1
0.17	-0.77	1
0.18	-0.74	2
0.19	-0.72	1
0.22	-0.66	1
0.25	-0.60	1
0.26	-0.59	1
0.32	-0.49	1
0.37	-0.43	1
0.42	-0.38	1
0.46	-0.34	1
0.47	-0.33	1
0.81	-0.09	1

APPENDIX J. SUPPORTING STATITICS FOR RISK ASSESSMENT MATRIX BRACKETS

Observation #	AVG SEVERITY RATIO (SR^{avg})	$Log_{10}(SR^{avg})$
1	0.01	-2.00
2	0.01	-2.00
3	0.3	-0.52
4	0.5	-0.30
5	0.5	-0.30
6	0.5	-0.30
7	0.5	-0.30
8	0.5	-0.30
9	0.7	-0.15
10	0.7	-0.15
11	0.7	-0.15
12	0.7	-0.15
13	0.8	-0.10
14	0.8	-0.10
15	0.8	-0.10
16	0.8	-0.10
17	0.8	-0.10
18	0.9	-0.05
19	0.9	-0.05
20	0.9	-0.05
21	0.9	-0.05
22	0.9	-0.05
23	0.9	-0.05
24	0.9	-0.05
25	1	0.00
26	1	0.00
27	1	0.00
28	1	0.00
29	1	0.00
30	1.1	0.04
31	1.1	0.04
32	1.1	0.04
33	1.2	0.08
34	1.2	0.08
35	1.2	0.08
36	1.2	0.08
37	1.3	0.11
38	1.4	0.15
39	1.4	0.15
40	1.4	0.15

Observation #	Relative Frequency (RF)	$Log_{10}(RF)$
1	0.001	-3.00
2	0.002	-2.70
3	0.002	-2.70
4	0.003	-2.52
5	0.003	-2.52
6	0.004	-2.40
7	0.01	-2.00
8	0.01	-2.00
9	0.01	-2.00
10	0.02	-1.70
11	0.02	-1.70
12	0.02	-1.70
13	0.02	-1.70
14	0.02	-1.70
15	0.02	-1.70
16	0.02	-1.70
17	0.03	-1.52
18	0.03	-1.52
19	0.05	-1.30
20	0.06	-1.22
21	0.06	-1.22
22	0.06	-1.22
23	0.07	-1.15
24	0.07	-1.15
25	0.07	-1.15
26	0.09	-1.05
27	0.09	-1.05
28	0.09	-1.05
29	0.09	-1.05
30	0.1	-1.00
31	0.1	-1.00
32	0.11	-0.96
33	0.12	-0.92
34	0.12	-0.92
35	0.13	-0.89
36	0.13	-0.89
37	0.14	-0.85
38	0.14	-0.85
39	0.14	-0.85
40	0.14	-0.85

Observation #	AVG SEVERITY RATIO (SR^{avg})	$Log_{10}(SR^{avg})$
41	1.5	0.18
42	1.5	0.18
43	1.5	0.18
44	1.6	0.20
45	1.7	0.23
46	1.8	0.26
47	2.1	0.32
48	2.1	0.32
49	2.1	0.32
50	2.4	0.38
51	2.7	0.43
52	2.8	0.45
53	2.8	0.45
54	2.8	0.45
55	3.1	0.49
56	14.7	1.17
	μ_{log10} =	0.045
	σ_{log10} =	0.22

Observation #	Relative Frequency (RF)	$Log_{10}(RF)$
41	0.15	-0.82
42	0.15	-0.82
43	0.16	-0.80
44	0.17	-0.77
45	0.18	-0.74
46	0.18	-0.74
47	0.19	-0.72
48	0.22	-0.66
49	0.25	-0.60
50	0.26	-0.59
51	0.32	-0.49
52	0.37	-0.43
53	0.42	-0.38
54	0.46	-0.34
55	0.47	-0.33
56	0.81	-0.09
	μ_{log10} =	-1.19
	σ_{log10} =	0.58

APPENDIX K. SURVEY DISTRIBUTION POINT CONTACTS

Tom McDonald – Center for Transportation Research and Education

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