

Highway Work Zone Safety Audits at the Construction Stage

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ABSTRACT

The nation's highways are in need of extensive maintenance and reconstruction work. High traffic demand requires state and local transportation agencies to consider practical strategies for minimizing a work zone's impacts on the traveling public and construction workers. Work zone safety audit is a proactive tool to serve the purpose. This paper presents the guidelines for highway work zone safety audits at the construction stage. After a brief description of the key features of work zone safety audit, an eight-step audit process is presented. Then, the article focuses on the five key audit tasks which are performed in the audit process including pre-audit reviews, audit meetings, audit field inspections, audit analyses and audit recommendations. Finally, a case study is introduced to show the proposed guidelines.

Keywords: Highway; Work zone; Safety audits; Construction stage; Guidelines.

INTRODUCTION

The Federal Highway Administration (FHWA) updated the former regulation *Traffic Safety in Highway and Street Work Zones* and published 23 CFR 630 Subpart J, *Final Rule on Work Zone Safety and Mobility* in 2004 to address work zone safety and mobility challenges facing all state transportation agencies that receive Federal-aid highway funding (1). The updated FHWA's final Rule emphasizes on development and implementation of agency-level policies to facilitate systemwide assessment and management of work zone safety and mobility impacts, network-level processes to support policy implementation, and project-level procedures to assess and manage the impacts of individual projects.

Road Safety Audit (RSA) is a formal, independent, and comprehensive road safety performance review conducted by an experienced team of safety specialists to maximize safety of the roadway environment for all highway users. It has been adopted by many state and local transportation agencies in the United State and abroad in the last several decades (2, 3, 4, 5, 6, 7, 8, 9). FHWA released the Road Safety Audit Guidelines in 2006 to further promote the use of road safety audits at various stages of a project, ranging from planning, programming, design and contracting, construction, to post-construction (10).

Motivated by the success of RSA, work zone safety audit (WZSA) is intended to assist work zone stakeholders in identifying potential safety and mobility hazards and to recommend practical measures for improving work zone safety and mobility. Similar to a RSA, a WZSA can be conducted at different project delivery stages. However, there are significant differences between a RSA and a WZSA. The RSA is mainly focused on the review of highway safety engineering issues concerning geometric design standards, consistency of geometric design, and pavement and bridge conditions, safety hardware, and roadside conditions. The WZSA aims at mitigating work zone's safety and mobility impacts on highway users and workers when a highway project is under construction.

The construction stage represents the stage in which the highway project is actually built in the field while the work zone presents to highway users. The decisions made during the planning, preliminary engineering, and design stages are implemented at this stage. During construction, the focus is on implementing the traffic control plan, managing the construction project, facilitating safety for motorists and workers, maintaining traffic flow through the work zone area, recordkeeping day-to-day project activities, and tracking project progress. At the construction stage, a WZSA should address three unique features of an active work zone: temporary work zone elements, continuously changing work zone conditions, and closely engaged project participating parties.

Many temporary traffic control hardware, devices, temporary construction elements are used in a work zone for setting up the work zone, channelizing traffic, providing information to road users, and assisting construction activity in the field. Construction materials, equipment, and other goods stored in the activity area may not be fully secured. Incomplete or in-progress construction work may be left at an unsafe state for workers and/or highway users.

Conditions in a work zone may change significantly from day to day. For instance, traffic lanes may be shifted; construction activities can be different; and the activity area can also move from location to location. These changes can significantly affect working and driving conditions in the work zone. Recommended corrective measures must be implemented promptly. Otherwise, they may become irrelevant and cannot have any intended benefits.

When a project is at its construction stage, several project participating parties including the owner's project management team, the design team, the contractor, and the traffic control team all have their designated staff working on the project. Depending on the project size and impacts, some staff may have their full time assignment on the project. They manage the daily operations and advance the construction progress. They have been observing the moving picture of the work zone changes. A formal procedure to get their inputs would assist the audit team in performing the audit. Moreover, the work zone safety enhancement measures recommended by the audit team will need these responsible personnel to get implemented.

At present, no guidelines are available for conducting work zone safety audit. This paper introduces the guidelines for highway WZSAs at the construction stage. It starts with an introduction of an eight-step audit process for WZSAs at the construction stage. Then, it discusses the five key audit tasks to be performed in the audit process. Finally, a case study of work zone safety audit performed on I-55 is used to show the proposed guidelines.

THE WORK ZONE SAFETY AUDIT PROCESS

Work Zone Safety Audit Steps

Figure 1 presents an eight-step audit process for WZSA (10). These steps include project identification, audit team selection, pre-audit reviews, audit meetings, audit field inspections, audit analyses, audit findings, and final report on implementation.

The project owner agency should select a candidate work zone for auditing. The agency should designate a responsible person to serve as the point of contact with the audit team. An independent audit team and a team leader should be selected by the project owner agency. In the pre-audit review step, the project owner's responsible person will compile all relevant project information and provide it to the audit team. The audit team will then review the information before the on-site visit.

After the audit team arrives at the project site, formal meetings will be scheduled with key project participants to help the audit team obtain pertinent information on project design and construction strategies, Transportation Management Plan (TMP), and current work zone operations. Next, the audit team will drive-through the work zone and construction activity area several times including at least one at nighttime. The audit team can use the drive-through experience to feel the work zone conditions and to observe the behavior of drivers, pedestrians, and workers, as well as the visibility of law enforcement.

Based on the information collected from pre-audit reviews, audit meetings, and audit inspections, the audit team can assess potential risks facing highway users and construction workers in the work zone and discuss on practical measures that could be implemented to improve the work zone safety and mobility performance. Subsequently, the audit team will present its findings and recommendations to the project owner and other key project participants.

Finally, the project owner will direct the implementation of the recommendations and communicate with the audit team leader on the implementation status. The audit team leader will submit a final report on audit findings and implementation of the recommendations.

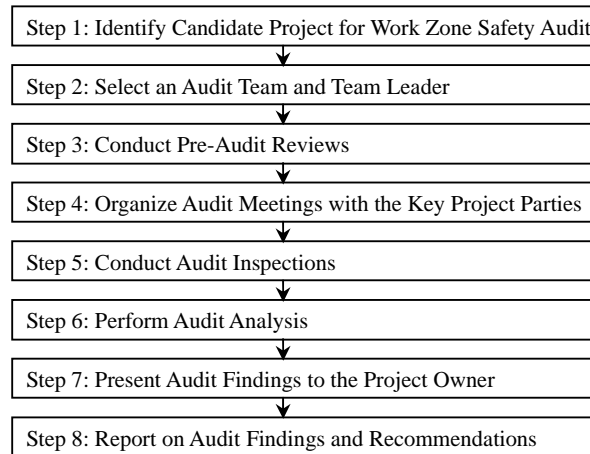


FIGURE 1 Work Zone Safety Audit Process

Work Zone Safety Audit Timeline

A WZSA at the construction stage should be conducted at the project site. An audit plan should be finalized 4-6 weeks before the site visit. The lead time will give the project owner and the audit team sufficient time to communicate about the upcoming audit, allow for the owner to compile the relevant project information and deliver the information to the audit team, and provide time for the audit team to review the information.

The status of a work zone may change dramatically in a couple of weeks. For most projects, 4-week lead time should be appropriate, but discretion can be used in determining the lead time by considering project size, complexity, impacts, and other factors. A 2-3 day schedule can be used for most work zone safety audits. A three day schedule is strongly recommended if the pre-audit reviews are to be conducted on-site. The proposed timeline is shown in Figure 2.

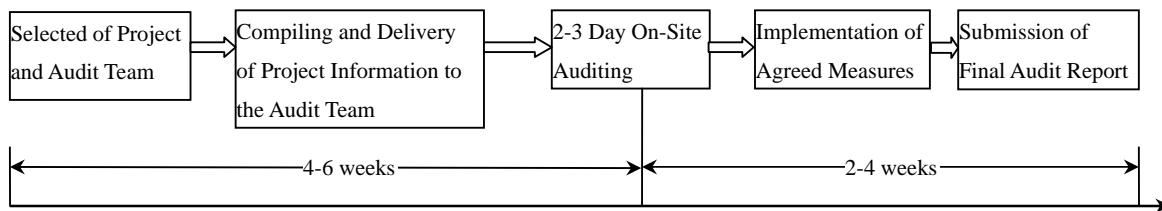


FIGURE 2 Work Zone Safety Audit Timeline

Following the on-site audit, the project participants will implement the agreed corrective measures on the project. Depending on the nature of the recommended measures, it may take a couple of days to a couple of weeks to have the measures implemented on the project. Due to the fast changing conditions in a work zone, a prompt implementation is extremely important for some measures. Otherwise, they will become irrelevant quickly as time goes by. At the end of the implementation period (typically 2-4 weeks), the project owner should report to the audit team leader on the implementation status of the agreed recommendations. In the meantime, the audit team will finalize its audit report. If there are policy- or agency-level changes recommended by the audit team, the report should be sent to the corresponding responsible offices or officials for consideration.

KEY TASKS OF WORK ZONE SAFETY AUDIT

Pre-Audit reviews

Pre-audit reviews enable the audit team to review project plans and documents before the planned audit. Pre-audit reviews can be performed either off-site or on the project site. If the off-site option is used, the above relevant information is prepared and delivered to the audit team members at least one week prior to the on-site audit to give the audit team sufficient time to review the information. If the on-site option is used, the audit team will spend one extra day in the project field office to review all relevant information. The project owner's responsible person can provide significant assistance for the audit team to locate relevant information.

Review the General Project Information

The audit team will review the project type and scope, duration, construction plans, traffic demand, work zone crash history, lane closure policies, queue length and delays, work restrictions, and public comments on the work zone to get a good understanding of the project background information. By reviewing the project general information, the audit team can get first hand knowledge about the project and its anticipated impacts on safety and mobility on the traveling public, communities and businesses in and around the work zone area.

Review of the Owner Approved TMP and Implementation of the TMP

A review of work zone impacts assessment and the project TMP will provide the audit team with information on the anticipated impacts of the work zone on safety and mobility. The selected work zone transportation management strategies in the TMP would ensure that the impacts could be managed at an expected level. The records of implemented transportation management strategies and actual safety and mobility performance will provide a means to assess the accuracy of estimated impacts and the effectiveness of the implemented transportation management strategies.

The FHWA's final Rule requires an early and proper identification of a significant project based on its impacts on safety and mobility and development of appropriate TMP. A TMP may include three components: Operations Management, Public Information, and Temporary Traffic Control. Regardless project significance level, the TMP must include the Temporary Traffic Control component. For projects that are not classified as significant, the Operations Management and Public Information components are not required, but are highly recommended by the FHWA's final Rule. In the pre-audit review, the audit team will review the latest version of the approved TMP and its implementation. The audit team should examine each selected work zone transportation management strategy to determine if: all key safety and mobility issues are adequately addressed, alternative transportation management strategies are properly compared, the selected strategies are justified, the benefits of the selected strategies are achievable, and the limitations of selected strategies are manageable.

Review of Agency Policies, Processes, and Procedures (Optional)

The FHWA's final Rule requires transportation agencies to systematically plan and manage work zone impacts by institutionalizing policy-level provisions, state-level work zone processes, and project-level procedures. The agency-level policy provisions will help agencies implement an overall work zone safety and mobility policy for systematic consideration and management of work zone impacts. The network-level processes will help agencies implement and sustain their respective work zone policies. These include requirements for addressing work zone impacts assessment, work zone data, work zone training, and process reviews for the entire highway network. The project-level procedures will help agencies assess and manage the work zone impacts of individual projects.

The mission of a WZSA team is to review project-level procedures for planning and managing the impacts of a given project work zone. The FHWA's final Rule requires that an agency must have a process review mechanism in place to periodically review its policy provisions and agency-level processes. To comply with this requirement, an agency may consider inviting the audit team to review the current policy provisions and agency-level processes governing its work zone practices so that the agency's policies and processes can be continuously improved.

Audit Meetings

A typical highway construction project involves four key parties: the project owner's project management team, the design team, the general contractor, and the traffic control team. These parties have developed a good understanding of the work zone configuration, its operations, and the effectiveness of implemented transportation management strategies. They will be invited to make formal presentations to the audit team to share their observations and perspectives. After a presentation, the audit team can ask questions to clarify any issues.

Presentation by the Project Owner's Project Management Team

The presentation by the project owner's project management team may cover, but is not limited to, the following areas: overall project scale and status, broad work zone management organizational and coordinating structure, safety training for the project personnel, work zone operation plan, transportation operations plan, incident management plan, emergency response plan, temporary traffic control plan, public information plan, monitoring of safety and mobility performance within the work zone and its affected areas, and observed best practices and deficiencies.

Based on the information collected from the pre-audit reviews and the presentation, the audit team may ask questions such as: Is there an adequate organizational structure for managing the work zone? Does the project team have sufficient staff, equipment, and financial resources to manage the work zone? Is there a clear communication channel between the key project leadership? Are there regular meetings among the key project leadership to discuss project staging/ phasing lane closure, speed enforcement, traffic and worker safety, mobility, and other issues? Is there an incident management plan in place? Is there an emergency management plan in place? Is speed enforcement consistent along the project alignment?

Presentation by the Project Design Team

Depending on the project owner agency's practice, the project design team may be comprised of the agency's in-house staff or consulting engineers. The project design team designs, revises, and supervises the daily operation of the implemented TMP. The project design team's presentation should cover, but is not limited to, the following areas: safety training of the on-site staff, preparation and implementation of the approved TMP, work zone operation strategies, work zone inspection procedure, record, and deficiency handling process, work zone emergency response procedure, major traffic incidents and vehicle crashes occurred in the work zone, best practices, deficiencies, and observed areas for improvement.

The audit team may also ask questions such as: Does the project design team maintain on-site staff with adequate traffic control knowledge and experience? Did the on-site staff receive safety training? Is the TMP adequately developed? Are any modifications of the TMP justified? Is the TMP properly implemented? What transportation management strategies are working? What strategies are not working?

Presentation by the General Contractor

The general contractor has the overall responsibility for constructing the project. For a significant project, the general contractor usually maintains an on-site safety engineer with an overall responsibility of ensuring safety in the work zone. The general contractor's representation should address, but is not limited to, the following issues: typical site layout plan, worker safety training, safety program and inspection plan, site operation plan to deal with interactions between passing through and construction traffic, traffic and construction incident management plans, safety monitoring and supervision on subcontractors, complaints from construction workers, worker injury records, and best practices, deficiencies, and observed areas for improvement.

The audit team can ask questions such as: Does the general contractor have proper safety training program, provisions to require workers' compliance with safety regulations? Does the general contractor have a construction safety plan? Are safety meetings held? Are workers informed of the safety regulations? Is the work zone secured properly with the barricades? Are controls in place for restricted areas requiring limited access? Are workers provided with and made to wear safety garments while working in vehicular traffic? Are flaggers knowledgeable of standard flag signals to control traffic effectively? Are employees properly trained and properly protected in the use of machinery and equipment they are operating? Are all machines regularly examined?

Presentation by the Traffic Control Team

The traffic control team may be from the general contractor or its subcontractor. The traffic control team is responsible for filing daily traffic control reports and maintaining traffic control devices up to the Manual on Uniform Traffic Control Devices (MUTCD) standards (11). The traffic control team's presentation can focus on, but is not limited to, the following points: safety training for traffic control staff, TMP implementation, traffic control devices maintenance plan, traffic incident management plan, emergency response plan, observed traffic condition, compliance of posted speed limits, and driver behavior, especially in peak rush hours, records of major incidents and crashes, best practices, deficiencies, and observed areas for improvement.

The traffic control supervisor's presentation can help the audit team answer some typical questions such as: Did the contractor's on-site staff receive safety training? Work zone setup: Is the channelization of traffic proper and clear? Are all the exits and entrances on the work zone unobstructed? Are all exits marked with a readily visible sign that is properly illuminated? Work zone access: Is the work zone secured properly? Are controls in place for restricted areas requiring limited access? Are all the warning and regulatory signs installed as per the specifications? Have the traffic signs been installed at the proper locations?

Audit Inspections

The purpose of audit inspections is for the audit team to have a first-hand experience of the work zone conditions. The audit team should drive through the work zone at least twice, once during the day and the other at night. In general, an audit inspection should cover, but not be limited to, the following three areas: experiencing the driving conditions in the work zone, inspecting temporary traffic control devices, and inspecting the construction activity area.

Experiencing the Driving in the Work Zone and the Surrounding Area

The multiple drive-through inspections at different times of the day (e.g. peak-hours and off-peak hours) will give the audit team a sense of the traffic conditions, work zone configuration, effectiveness

of signs, signals, lighting, markings and delineation, guardrails, barriers, and crash cushions, and behavior of drivers and pedestrians, queue lengths, delay time, actual travel speeds, compliance of the posted speed limits, and the visibility and feasibility of speed enforcement. Stops can be made during the drive-throughs for close inspections. Videos and photos may be taken to document observations. The audit team can make cross comparisons of the information obtained from pre-audit reviews and audit meetings with their actual observations.

Inspection of Temporary Traffic Control Devices

Temporary traffic control devices include signs, signals, lighting, markings and delineation over or adjacent to a streets, highways, pedestrian facilities or bikeways by authority of a public body or official having jurisdiction to provide warning and guidance to highway users, primarily including drivers, pedestrians, the contractor's vehicle and equipment operators. The MUTCD requires all traffic control devices meet a minimum standard and be adequately maintained. The audit team can refer to the MUTCD for detailed information.

Inspection of Construction Activity Area

The MUTCD outlines the following safety elements be addressed for construction worker safety: workers' safety training, worker safety apparel, temporary traffic barriers for work spaces, speed reduction, work area, and worker safety planning.

All workers should be trained on how to work next to motor vehicle traffic in a way that minimizes their vulnerability. All workers exposed to the risks of moving roadway traffic or construction equipment should wear high-visibility safety apparel meeting the requirements of ISEA "American National Standard for High-Visibility Safety Apparel" (12). A responsible person designated by the contractor for the worker safety plan within the activity area of the job site should make the selection of the appropriate class of garment.

Temporary traffic barriers should be placed along the work space depending on factors such as lateral clearance of workers from adjacent traffic, speed of traffic, duration and type of operations, time of day, and volume of traffic. Reducing the speed of vehicular traffic, mainly through regulatory speed zoning, funneling, lane reduction, or the use of uniformed law enforcement officers or flaggers, should be considered. Planning the internal work activity area to minimize backing-up maneuvers of construction vehicles should be considered to minimize the exposure to risk.

The contractor should prepare a worker safety plan. A responsible person designated by the contractor should conduct a basic safety hazard assessment for the work site and job classifications required in the activity area. This designated worker safety management staff should determine whether engineering, administrative, or personal protection measures should be implemented. This plan should be in accordance with the Occupational Safety and Health Act of 1970.

The audit team should drive-through the construction activity area to experience entering and exiting the activity area. By observing the site layout and activities performed by the workers, the audit team can assess how the safety plan is actually implemented and how workers comply with safety regulations in the field.

Audit Analyses

This step offers an opportunity for the audit team to consider pertinent information collected from pre-audit reviews, audit meetings, and audit inspections, and to discuss and even debate among

themselves on potential risks and practical mitigation measures. The audit analyses may cover the following areas:

Overall Work Zone Management and Coordination

Effective communication and coordination among the key project participants are essential to accomplish the goal of minimizing the work zone impacts on safety and mobility. Coordination meetings should be regularly scheduled to bring together all project stakeholders to take steps towards project implementation, to foresee potential problems, and to identify solutions to mitigate the problems in a proactive manner. The audit team can review the existing communication channels for project coordination, such as reviewing meeting schedule, attendants, and meeting minutes.

Transportation Operations Management Plans

According to the FHWA's final Rule, a Transportation Operations Management Plan is required as part of the TMP for a significant project in order to mitigate work zone impacts on the transportation system. Typical operations management strategies include: demand management strategies, corridor/network management strategies, incident management and enforcement strategies, and work zone safety management strategies. This analysis may be skipped for insignificant projects that do not have a Transportation Operations Management component. The audit team can evaluate the effectiveness of the implemented strategies for transportation operations management.

Public Information Plans

According to the FHWA's final Rule, a Public Information Plan is required for a significant project, and is recommended for other types of projects. The audit team can evaluate the effectiveness of the implemented strategies.

Temporary Traffic Control Plans

A Temporary Traffic Control Plan is required for all work zones to ensure safe movement of traffic through and around the work zone. Temporary traffic control strategies are categorized in three categories as follows: traffic control strategies; traffic control hardware and devices; and project coordination, innovative contracting, and innovative construction strategies.

Construction Worker Safety

The General Contractor must comply with the MUTCD and the Occupational Safety and Health Administration (OSHA)'s safety regulations (13, 14). Based on the contractor's presentation and field inspections of the activity area, the audit team can evaluate adequacy of the contractor's worker safety program such as: Does a full set of the construction safety plan exist? Is the staff informed about the safety regulations? Is there a primary person responsible for worker safety? Is there a culture for safe operations in the company? Does the company keep a record of its safety inspections? Are all workers informed of the safety regulation on the construction site? Are there routine internal safety inspections? Are there routine safety meeting or training in the company?

Monitoring Work Zone Safety and Mobility Impacts during Construction

After construction begins, the key project participants should jointly monitor the actual work zone impacts on safety and mobility. It's the project owner's responsibility to determine if the actual impacts fall within a reasonable range as predicted in the work zone impacts assessment that formed the basis of developing the project TMP. The audit analyses can examine the following issues: a comparison of the actual and anticipated work zone safety impacts, the effectiveness of the implemented TMP, innovative traffic control, contracting, and construction techniques/ technologies

used in the project, best practices and lessons learned, and recommendations for changes in agency-level policies, network-level processes, and project-level procedures.

While specific issues vary from project to project, the major performance aspects to monitor/measure include safety, recurring congestion in peak periods, non-recurring congestion due to incidents, community and environmental impacts, and combined impacts with nearby, concurrent projects. Congestion in the work zone can also affect project efficiency. Issues such as delays to construction vehicles for delivering materials to the work zone may be indicators of work zone congestion. Depending on the project, feedback from businesses, residents, and neighborhood groups may also be useful indicators of the work zone performance. If the actual work zone impacts on safety and mobility are within acceptable range of safety and mobility performance levels, no change in the TMP is needed. Otherwise, the project owner should take necessary actions to mitigate the impacts, including modifying the TMP.

Audit Findings and Recommendations

Based on the audit analysis results, the audit team will present its findings to the key project participants, including project owner, the project design team, the general contractor, and the traffic control team at the audit closeout meeting. The audit team should also discuss its recommendations for mitigating work zone impacts on safety and mobility extensively at the meeting and obtain direct input from the key parties on the implementability and an implementation plan. The recommendations may be divided in the following three categories: potential safety hazards that need to be corrected immediately, recommended changes in project-level procedures, and recommended changes/adoption on agency-level or network-level policies and possesses.

A CASE STUDY

Background

A WZSA was conducted during a two day period on July 30 and 31, 2007 on Interstate 55, between portions of US 6 and Weber Road (http://safety.fhwa.dot.gov/rsa/rsa_samplerpts.htm). The focus of the audit was to identify opportunities for safety improvements in work zone areas. Throughout the study, the audit team examined several risk factors that impact traffic safety on Interstate 55, including exposure, probability, and consequence. The authors participated in the entire WZSA process as observers. The following section discusses the project as a case study to illustrate the proposed work zone safety audit guidelines presented above.

Selection of Audit Team

The work zone safety audit team was comprised of four members respectively from the FHWA, Illinois DOT (project owner), and Illinois State Police with one member serving as the team leader. All of them had no direct involvement in the project to avoid conflicts of interest.

Pre-Audit Reviews

Prior to the audit, the audit team requested for information on project design, construction, and transportation management strategies. The reviews were conducted on-site. The team looked for skid marks and broken glass and plastic materials to identify locations of crashes and near misses. Also, the team asked the project owner's Resident Engineer about any crash incidents and traffic problems.

Work Zone Safety Audit Kickoff Meeting

The audit began with an introductory meeting where the work zone safety audit team explained the safety audit process to the project owner and design team. Then the project owner and design team

provided all available, pertinent project information about existing site conditions, construction and work zone management plans.

Audit Inspections

The audit team used two vans to drive through the work zone area on each bound twice at different times. Emphases were given to the adequacy and deficiency of installed temporary traffic control hardware and devices, travel way surface conditions, traffic channelization and delineation, lane closure and merge, driver behavior, speed enforcement, and roadside conditions, etc. One drive-through was made in the evening of the first day to specifically examine the retroreflectivity of pavement markings and signs and the illumination of devices mounted on the barriers. Photos and video clips were taken by all audit team members.

Audit Analyses

The audit analyses focused on determining the safety hazard risk ratings for work zone safety issues identified in pre-audit reviews and audit inspections, recommending countermeasures to mitigate the risk hazards, and promoting best practices for broad adoption in future projects.

Development of Risk Matrix for Safety Hazard Risk Ratings. Risk is defined by the degree of frequency and severity of expected crashes for each safety issue and given an overall rating level as presented in the following:

$$R = f(E, P, C)$$

where

R = Risk level

E = Traffic exposure, total traffic exposed to the specific risk being assessed

P = Crash probability, the likelihood of a crash occurring.

C = Crash consequence, the severity of a crash once it happens.

The risk assessment matrix of potential work zone safety hazards was adopted from evaluating in-service roads as Table 1.

TABLE 1 Risk Matrix Used for Safety Hazard Risk Ratings

Risk Level (R)		Crash Severity (C)		
		Low	Medium	High
Crash Frequency (E x P)	Low	A	C	D
	Medium	B	C	E
	High	C	D	F

Risk Levels: A- Minimal; B- Low; C- Moderate; D- Significant; E- High; and F- Extreme.

Risk Ratings of Identified Safety Hazards and Counter Measures. After each safety issue was identified, the audit team subjectively estimated a probability of occurrence and corresponding severity of the crash. Based on the matrix of Table 1, a risk rating can be obtained for the identified safety issue. Finally, practical countermeasures were suggested by the audit team to mitigate the perceived work zone hazards. The countermeasures were classified into long-term, medium-term, and immediate actions which the project owner could take. Typical immediate measures required quick implementations to accomplish their expected safety benefits in the current work zone. Long-term measures usually require the project owner agency to consider policy or procedure changes which will

benefit future work zones. The identified safety hazards, their expected risk ratings, and recommended counter measures of this audit are summarized in Table 2.

Best Practices. The audit team also discovered several best practices in the audit. First, the traffic control plan which recommended trucks to use the left lane was a good idea for this type of project considering that the work zone was using the shoulder as the right lane. This would minimize damages to the shoulders, kept trucks off the locations where adverse superelevation and/or changes in shoulder slopes at bridges, and simplified operations at ramp terminals. Second, the drums placed along the median pavement edge throughout the work zone emphasized the presence and continuity of the work zone. Finally, there was good overall nighttime guidance through the work zone. Traffic control devices were clearly visible and well placed for effectiveness.

Closeout Meeting

Upon completion of the assessment, the audit team presented identified safety issues along with suggested countermeasures to the project owner, design team, the general contractor, and traffic control team at the closeout meeting in the afternoon of the last day of the audit. This was accomplished by open discussions among the audit team and the key project participants. At the end of the meeting, a take-away list of actions was agreed upon by the participants as follows:

- Remove conflicting striping SB at IL 126 (second edge stripe about 4' onto shoulder)
- Guardrail delineation
- Object removal from shoulder, priority to damaged guardrail
- Flag "Trucks Use Left Lane" static signs (2 flags or according to MUTCD)
- Changeable Message Signs "THRU TRUCKS LFT LANE"
- Add speed limit signs between lane tapers at needed locations
- Trim vegetation obscuring signs.

Final Audit Report and Owner's Response Report

Following the closeout meeting, the audit team submitted a formal written report to the project owner summarizing all identified safety issues and suggested countermeasures. Different from a typical road safety audit, the project owner's response was not required as suggested by the audit team since the owner had already committed to the take-away list at the closeout meeting and the audit team would send the report with the other recommended long-term measures to proper offices for consideration.

SUMMARY AND CONCLUSIONS

This paper presented the guidelines for highway work zone safety audit at the construction stage. It described the key features of a work zone safety audit and an eight-step audit process. The, the five key audit tasks in the WZSA process were discussed in detail. Finally, a case study was presented to illustrate an application of the proposed guidelines on an I-55 work zone from US 6 to Weber Road, Will County, Illinois. Our observation of the safety audit also indicated that the work zone safety audit helped the project participants enhance their understanding of the potential risks facing the work zone. Work zone safety audit can be used as proactive safety tool to improve work zone safety and mobility performance.

TABLE 2 Risk Levels of Identified Potential Safety Hazards in the Work Zone

Safety Hazard		Expected Crash				Recommended Countermeasure		
		Type	Frequency	Severity	Risk	Immediate	Intermediate	Long-Term
Geometric Design	Stage I construction with 11-ft narrow lanes	Sideswipe same direction, fixed object	Medium	Medium	C	Ensure effective and accurate striping	Stage I completion dates to minimize exposure	
	Use of narrow shoulders leaves barriers in shy zone	Sideswipe same direction, fixed object	Medium	Medium	C	Guardrail delineation	Effective and accurate striping	Policy on min of 11-ft lanes and 2-ft shoulders, with narrow lane signs
	Resurfacing of shoulders carrying traffic results in adverse superelevation	Fixed object, overturn	Low	Medium	C			Stage I completion dates to minimize exposure
Signs	Many signs in close proximity of lane shift approaches	Sideswipe same direction	Low	Low	A			Develop policy and/or standards to address this issue
	Lack of dual display of work zone signs	Sideswipe same direction, rear end	Medium	Low	B		Policy and/or standards to address this issue	
	Confusing arrow signs on Type 3 Barricades	Sideswipe same direction	Low	Low	A	Effective and accurate striping	Stage I completion dates to minimize exposure	
	Signs for trucks to use the left lane is not prominent and message does not address trucks using exits	Sideswipe same direction, rear end	Medium	Low	B	Addition of flags to signs, portable signs on all ramps, "THRU TRUCKS LFT LANE" verbiage to variable message signs		

TABLE 2 Risk Levels of Identified Potential Safety Hazards in the Work Zone (Continued)

Safety Hazard		Expected Crash				Recommended Countermeasure		
		Type	Frequency	Severity	Risk	Immediate	Intermediate	Long-Term
Signs (Continued)	The overlay plaques of speed limit signs do not match panel font or retroreflectivity	Sideswipe same direction, rear end	Low	Medium	C	Improvement of overlay panels for consistency in font and retroreflectivity		
	Ambiguity of speeds between the work sites	Sideswipe same direction, rear end	Medium	Medium	C	Addition of speed limit signs between lane shifts		
Pavement Markings	Conflicting pavement markings	Fixed object, sideswipe same direction	Low	Low	A	Removal of previous striping	Resurfacing of critical locations before re-striping	Research for a nondestructive method to remove striping
Guardrails	Guardrails below allowable height	Fixed object	Low	Medium	C	Addition of guardrail delineation	Assurance of crashworthy guardrail at design stages	
	Delineation of guardrail and barrier walls	Fixed object, sideswipe same direction	Low	Low	A	Installation of guardrail reflectors on all guardrail and barrier walls		Policy on guardrail and barrier wall delineation
Vegetation and Debris Control	Vegetation blocks view of some signs	Fixed object, sideswipe same direction	Low	Medium	C	Trimming of vegetation obscuring signs		
	Objects present on shoulders	Other object, sideswipe same direction, rear end	Low	High	D	Garbage removal, priority to damaged guardrails		
Human Behavior	Speeding and aggressive driving	All	Medium	High	E	Improvement of speed limit signage	Enforcement by police or van	Policy on speed management

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REFERENCES

1. NARA (2004). Final Rule on Work Zone Safety and Mobility. *Federal Register* 69(174), 54562-54572., National Archives and Records Administration, Washington, D.C.
2. IHT (1996). Guidelines for the Safety Audit of Highways. Institution of Highways and Transportation, London, United Kingdom.
3. DRD (1997). Manual of Road Safety Audit. Danish Road Directorate, Copenhagen, Denmark.
4. TAC (2001). The Canadian Road Safety Audit Guide. Transportation Association of Canada, Ottawa, Canada.
5. AUSTRROADS (2002). Road Safety Audit Guide, 2nd Edition. Austroads, Sydney, NSW, Australia.
6. Giuffrè, O., A. Di Francisca, A. Granà. (2002). Road Safety Audit Effectiveness at Urban Junctions. In *The Sustainable City II*. CA Brebbia, C.A., J.F. Martin-Duque, L.C. Wadhwa (Editors). WIT Press, Southampton, United Kingdom.
7. CEC (2004). Guidelines for Highway Safety Audit. Chelbi Engineering Consultant Inc., Beijing, China.
8. NRA (2004). Road Safety Audit Guidelines. National Roads Authority, Dublin, Ireland.
9. NCHRP (2004). Road Safety Audits. *NCHRP Synthesis 336*. Transportation Research Board of the National Academies, Washington, D.C.
10. FHWA (2006). FHWA Road Safety Audit Guidelines. *Report No. FHWA-SA-06-06*. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C.
11. FHWA (2003). Manual on Uniform Traffic Control Devices. Federal Highway Administration, U.S. Department of Transportation, Washington D.C.
12. ISEA (1999). American National Standard for High-Visibility Safety Apparel. ANSI/ISEA 107-1999. International Safety Equipment Association. Arlington, VA.
13. NIOSH (2001). Building Safer Highway Work Zones: Measures to Prevent Worker Injuries From Vehicles and Equipment. National Institute for Occupational Safety and Health, Department of Health and Human Services, Cincinnati, OH.
14. OSHA (2006). The Roadway Work Zone Safety and Health Coalition (www.osha.gov/dcs/alliances/work_zone/work_zone.html). Occupational Safety and Health Administration, U.S. Department of Labor, Washington, D.C.