FINAL REPORT

# Traffic Control Systems in Construction Work Zones

## Project VD-H1, FY 97

Report No. ITRC FR 97-5

Prepared by

Richard A. Raub,
Omar Sawaya,
Joseph L. Schofer
and
Athanasios Ziliaskopoulos
Traffic Institute
Northwestern University
Evanston, Illinois

February 2001

**Illinois Transportation Research Center**
**Illinois Department of Transportation**

# ILLINOIS TRANSPORTATION RESEARCH CENTER

This research project was sponsored by the State of Illinois, acting by and through its Department of Transportation, according to the terms of the Memorandum of Understanding established with the Illinois Transportation Research Center. The Illinois Transportation Research Center is a joint Public-Private-University cooperative transportation research unit underwritten by the Illinois Department of Transportation. The purpose of the Center is the conduct of research in all modes of transportation to provide the knowledge and technology base to improve the capacity to meet the present and future mobility needs of individuals, industry and commerce of the State of Illinois.



## Illinois Transportation Research Center Members



Reports may be obtained by writing to the administrative offices of the Illinois Transportation Research Center at Southern Illinois University Edwardsville, Campus Box 1803, Edwardsville, IL 62026 [telephone (618) 650-2972], or you may contact the Engineer of Physical Research, Illinois Department of Transportation, at (217) 782-6732.

**Technical Report Documentation Page**

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| ITRC FR 97-5 | | |

**4. Title and Subtitle**

Traffic Control Systems in Construction Workzones

**5. Report Date**

February 2001

**6. Performing Organization Code**


**7. Author(s)**

Richard A. Raub; Omar Sawaya; Joseph L. Schafer; Athanasios Ziliaskopoulos


**8. Performing Organization Report No.**

**10. Work Unit No. (TRAIS)**


**9. Performing Organization Name and Address**

Northwestern University Traffic Institute
405 Church Street
P.O. Box 1409
Evanston, Illinois 60240


**11. Contract or Grant No.**

VD-H1, FY 97


**12. Sponsoring Agency Name and Address**

Illinois Transportation Research Center, Administrative Office
Southern Illinois University at Edwardsville
Engineering Building, Room 3026, Edwardsville, IL 62026


**13. Type of Report and Period Covered**

Final Report
November 1997 – October 1999

**14. Sponsoring Agency Code**

**15. Supplementary Notes**

**16. Abstract**


Traffic control devices in workzones are intended to provide sufficient guidance to motorists to help prevent collisions, especially with construction operations, and based on study of their use in Illinois, they appear to be meeting the objectives. What has been discovered in assessing workzone traffic control and crashes is that collisions occur more frequently than reports show an in ways not necessarily addressed in previous studies. For the most part, traffic control devices (TCD) within the actual construction area require not changes. They are protecting the workers from the motorists. What leads to collisions inside the work area are reduced lane widths and lack of adequate escape, especially on limited access roadways. As a result, the most frequent type of collision is rear-end often caused because drivers stopping or suddenly slowing often because of distractions. Outside the work area, the problem appears more related to poor driving behavior and need for some improved guidance for motorists especially within the merge areas.

When taking into account the under-reporting, of crashes with the exception of increases in certain manners of collision such as rear-end, the crashed appear no more severe than crashed occurring outside such zones. Crashes with pedestrians (which includes workers) also appear no more likely than in locations without workzones. On the other hand, crash reporting appears unlikely to include portions of the workzone away from the actual construction area.

Using a set of crash reports in which the workzone was defined clearly to include the approach, taper, and exit, analysis suggest that crashes are almost as likely to occur outside the actual construction area as within. It is these crashes outside which appeared more severe and more amenable to enhanced traffic control, especially enforcement. The report recommends practices which could reduce crashes in the approach and where changes or reductions in lanes occur. In addition to other recommendations, a model for a process to be used in generating and reviewing workzone traffic controls has been developed.



**17. Key Words**

Workzone, Traffic Control, Crash, Driver Behavior


**18. Distribution Statement**

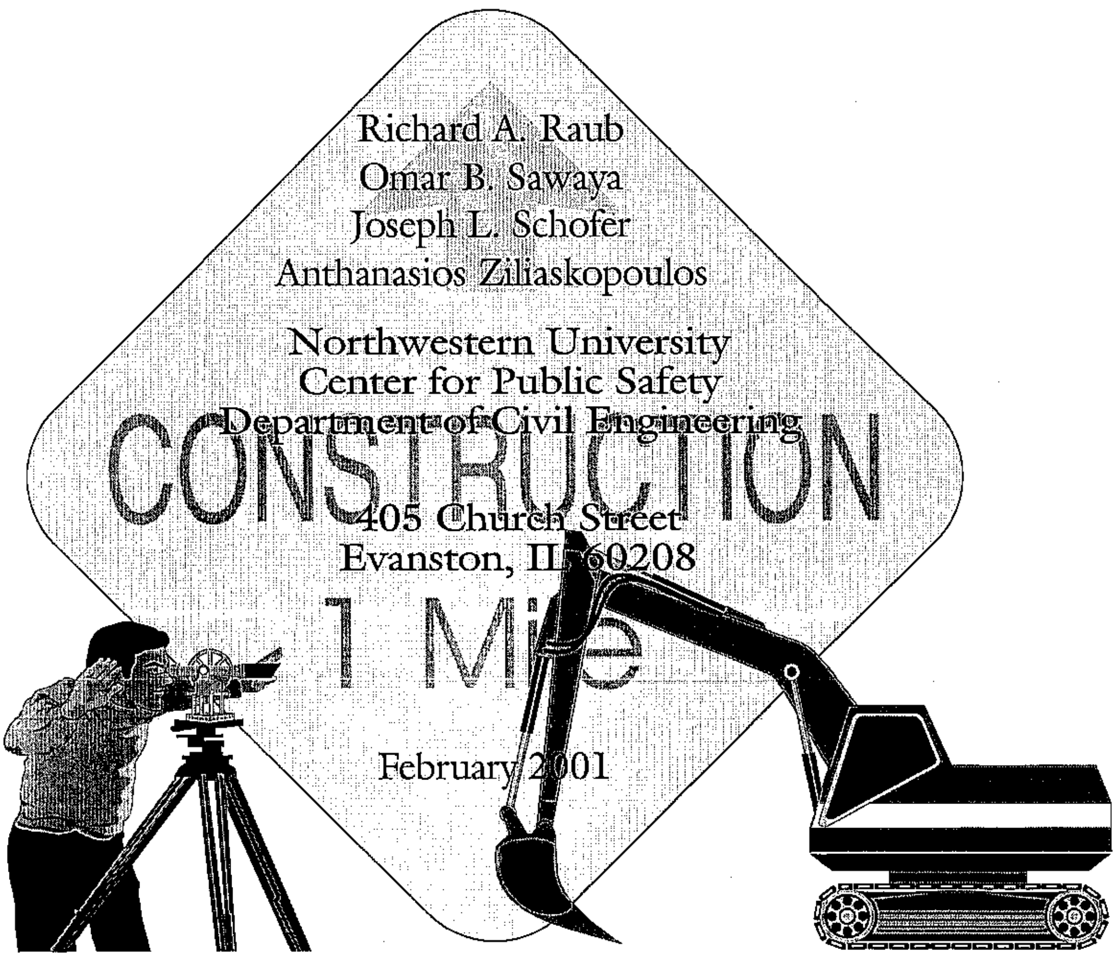
No restriction. This document is available to the public through the National Technical Information Services (NTIS), Springfield, Virginia 22161

| 19. Security Classification (of this report) | 20. Security Classification (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 244 | |

# Traffic Control Systems in Construction Workzones
# Final Report

for the
ILLINOIS DEPARTMENT OF TRANSPORTATION

Illinois Transportation Research Center




Richard A. Raub
Omar B. Sawaya
Joseph L. Schofer
Anthanasios Ziliaskopoulos

Northwestern University
Center for Public Safety
Department of Civil Engineering

405 Church Street
Evanston, IL 60208

February 2001

**Acknowledgments**

The authors wish to acknowledge the work of James Schoenherr and Joyce Schroeder of the Illinois Department of Transportation, Springfield as members of the Technical Review Panel for their review and critique of the work. A special thank you goes to Phil Palmer and Karen Magee, also of the Springfield Office, for their significant effort in making available the IDOT crash database records for analysis. Those records provided substantial insight into the crash data being recorded for workzones.

Additional acknowledgments go to District Engineers who made available construction plans reviewed and used in the statistical analysis: District 1: Tom Leverenz, District 4: Allan Hultgreen, District 5: Mark Reeley, District 6: Bill Jacquot. A number of Resident Engineers provided time to help the project team understand issues and resolution of those issues as they applied to construction workzones. Also to Ken Glassman of the Illinois State Toll Highway Authority.

Crash data and the supplemental reporting was made possible through the assistance of the Illinois State Police, the commanders and troopers of Districts 5, 7, 15, and 17, the Northbrook Police Department, James Wallace, Chief, and the Lake County Sheriff's Department, Gary Del Re, Sheriff. A special thank you goes to Captain Leroy Norman and the officers of ISP District 15 (Illinois Tollway) for assisting in developing the supplemental reporting form for workzone crashes.

The Transportation Library at Northwestern University, Mr. Robert Sarmiento, Director, provided their never ending assistance throughout the project helping with literature searches and with supplying documents when needed. Special mention is made of Ms. Dorothy Ramm and Ms. Mary McCreadie.

Finally, Dung Le Doan, Hediye Tuydes, John Gliebe, and Daniel Helms, doctoral candidates and graduate students from the Department of Civil Engineering, assisted with the onsite data collection and with developing the driver behavior interpretations.

**Traffic Control Systems in Construction Workzones**
**Final Report**

## Table of Contents

## Table of Contents (cont'd)

**Table of Contents (cont'd)**

## Table of Contents (cont'd)

## Table of Contents (cont'd)

## List of Tables

**List of Tables** (cont'd)

## List of Figures

## Traffic Control Systems in Construction Workzones
## Final Report

### Executive Summary

#### Purpose of the Study

The investigation of traffic controls used in workzones was designed to identify how the traffic control plan (layout for traffic operations in workzones) and traffic control devices affect driving and traffic safety. Specific objectives included:

- determining the typical locations of and conditions under which motor vehicle crashes occur at Illinois roadway construction locations.
- reviewing the characteristics of typical IDOT workzone traffic control plans and, based on historical and current crash data, to identify the factors that may contribute to the occurrence of crashes in construction areas.
- developing statistical models that relate workzone crashes with the various elements of traffic control and assess their statistical significance.
- recommending changes in the design of traffic control systems which would improve safety in the zones, including costs of these changes.

To accomplish these objectives the project was divided into three tasks: a) identify what is known about the relationship between traffic controls and traffic control plan in workzones and crashes, b) gain a better understanding of these elements with motorist behavior through onsite observations, and c) recommend changes in traffic management that could help reduce crashes. Historic crash data was crucial to the project. Analysis of these data and the literature provided the basis for planning site selection and conducting observations.

#### Structure of the Study

The proposed study addressed a number of tasks which are reported.

1. Address issues and recommendations as contained in the literature.
2. Obtain and analyze workzone crash data using the abstracted data from the Illinois Department of Transportation database, augmenting the analysis with review of individual reports as needed.
3. Conduct onsite observations of workzones in selected areas through the state to observe how motorists behave in the zones and relate that behavior to the TCP and TCD.
4. Use supplemental reporting forms with the Illinois Police Crash Report allowing police who report crashes at selected workzones to more completely describe contributing factors.
5. Provide recommendations and test concepts.

## Important Findings

Workzone traffic control in Illinois appears to be effective for the purpose of controlling the movement of vehicles while separating them from the workers. However, workzones continue to be more dangerous when comparing the number of crashes occurring during construction with those occurring before and after the work.

The research team discovered that although traffic control plans (TCP) for workzones appeared to follow the standards, during the course of the project Resident Engineers (RE) made changes in response to local conditions, actual construction, and crash information. Normally, these changes are not documented on the construction plans, although, the RE may record them in field diaries, memorandum, or other sources. The fluidity inherent in the TCP is addressed in the model described in the final section of this report.

Several other key findings are addressed:

1. Crashes within the working area (the area designated for actual construction) are likely to continue primarily because the trade-off needed to keep traffic moving and to protect workers results in narrow lanes and the lack of escape. However, the crashes which occur are minor (mostly resulting in property damage) and involve workers or their equipment relatively infrequently.
2. Outside the working area, crashes in the approach and transition were found to be more likely to be injury causing than those occurring elsewhere. Previous research has provided very limited coverage of the approach and transition to the working area.
3. The current mechanics of reporting workzone crashes leads to substantial under-reporting which, in turn, limits the information which can be used to assist in designing countermeasures.
4. Adjusting for the under-reporting, Illinois workzone crash analysis shows the following: crashes generally involve two or more vehicles, are rear-end, and occur on the week days. Workzone crashes are no more likely to produce injuries than crashes occurring on similar roadways where workzones are not present.
5. Where travel lanes are reduced on multi-lane roadways, the merging behavior of drivers may play a critical role in the likelihood of crashes both on the approach to and inside the actual working area.

## Summary of Recommendations

The onsite observations, analysis of crash reports, videotaping of driver behavior, and the literature led to a number of recommendations. With few exceptions, costs of implementing these recommendations would be minimal. The recommendations are summarized below:

1. The RE selected for the project should apply his or her expertise in developing the layout and TCP. Moreover, the Illinois Department of Transportation (IDOT) construction supervisors and resident engineer should inspect the entire construction area from the perspective of the driver before implementing it. Frequent inspections of the TCP and TCD are warranted.

2. Physical separation of motor vehicles and workers (especially through the use of "Jersey" type concrete barriers) has proven very effective in reducing crashes involving workers and their equipment. While it may increase the likelihood of minor collisions between motorists, such separation should be implemented wherever possible. Moreover, workers, their vehicles, and other construction equipment need to be kept separate from the travel stream at all times.
3. Because many of the crashes between motor vehicles can be linked to distractions from the activity within the workzones, some form of shielding the work from view can be considered, especially on highly congested roadways.
4. Consistent merging patterns should take place during the entire project when the number of lanes are reduced or even crossed over into two-way traffic configurations.
5. Because vehicle speeds on the approach and transition (taper) portion of the workzone (as opposed to inside the working area) appear to contribute to crashes, lower posted speed limits and increased enforcement may prove effective. Traffic enforcement also can be employed prior to the working area to reduce dangerous behaviors.
6. Additional research is needed to determine how best to achieve efficient merging.
7. Changes to the Illinois Traffic Crash Report are needed to reduce under-reporting of crashes. These changes should be consistent with the Minimum Uniform Crash Coding (MUCC 1997) standards, include the entire workzone, and include better police training for crash reporting.
8. Flaggers, where view of the entire site is not possible, need better communication between them to ensure that the last vehicle traveling through the site has cleared, and communication with the work supervisor to ensure that changes in activity will not affect motorists to be released into the site.
9. Additional research recommended:
    a. Study the most effective method of moving vehicles (maximum flow) through a transition under congested (queuing) conditions. Two choices are offered: the "Indiana" merge where vehicles are required to merge in the free-flowing stream, and the Pennsylvania "late merge" (Byrd, *et al.* 1999) where motorists are encouraged to merge at the taper.
    b. Assess use of variable speed limits in the approach portion of the workzone to slow motorists prior to reaching the queue. This effort must be coupled with a change in enforcement philosophy that removes speed enforcement from the working area (this report indicates this to an area where speeding is not a contributing factor) and redirects it to the approach area (where high speeds appear to be a contributor to crashes and their severity).
    c. Determine the effectiveness of posting workzone warning data only when work (or queuing) actually is occurring.

The report calls for a process model for the continuous monitoring of workzones. This will provide detection of problems and response when problems occur rather than at some later date. It uses data from crashes when they occur, and as compared to a history of crashes to determine what factors are related to causality and to take corrective action.

## Concluding Commentary

Workzone traffic controls and the workzone traffic control plan appear to provide adequate information regarding the construction area. The TCD and TCP have been developed from significant experience across the nation with construction projects and from a substantial body of research. Research based on data made available from IDOT suggest that crashes are more likely to occur in workzones, but that most of these crashes are minor. The largest single area of concern is the approach and taper. Supplemental reporting accompanying crash reports suggested that the greater dangers existed at these locations rather than within the construction area itself. On roadways where the construction was separated from the traffic by "Jersey" type barriers, almost all of the crashes involved transiting vehicles; workers and their equipment rarely were involved and when so, they were outside of their assigned areas.

What appeared to be more pressing problems are: 1) tailoring the TCP and TCD to specific locations, 2) gathering and using data about crashes, and 3) modifying motorists behavior. The two most notable deficiencies with reporting was that crashes occurring within workzones were not reported as such (under one estimate, as high as 85%), and even when reported as occurring in a "construction zone," were lacking in sufficient detail, or were improperly located, so as to be of limited value.

Much of the work was devoted to motorist behavior at the approach and taper because the more serious crashes appeared to have occurred at these locations. It is then the approach and taper where the research suggests that most value will be achieved by 1) improved TCD that help slow and guide motorists into the new configurations, 2) crash reporting that pays attention to this area, and 3) enforcement devoted to the approach rather than inside, especially where physical separation of vehicles and work occurs.

Finally the report has set forth a number of recommendations and a process model for continuously monitoring a particular workzone and investigating workzone crashes by collecting, analyzing and utilizing experiences at an individual workzone for safety enhancement. In addition to developing exposure measures and formulating recommendations to evaluate safety measures during the planning and designing stages of the workzone, the process uses continuous monitoring to detect, investigate and analyze workzone crashes and identify countermeasures. Two key components are a task force charged with the responsibility for safety at each workzone, and an enhanced crash reporting scheme.

This process offers a constructive method for limiting the number of crashes at specific workzones. By capturing, analyzing and accurately reporting the workzone crash information, the most promising targets for future research can also be identified. Eventually, with an accurate data set, the crash rate patterns of a given workzone might be anticipated, which in turn may allow for cost effective monitoring of workzones and the investigation of their crashes while enhancing workzone safety.

# Traffic Control Systems in Construction Workzones
# Final Report

## 1. Introduction and Structure of the Project

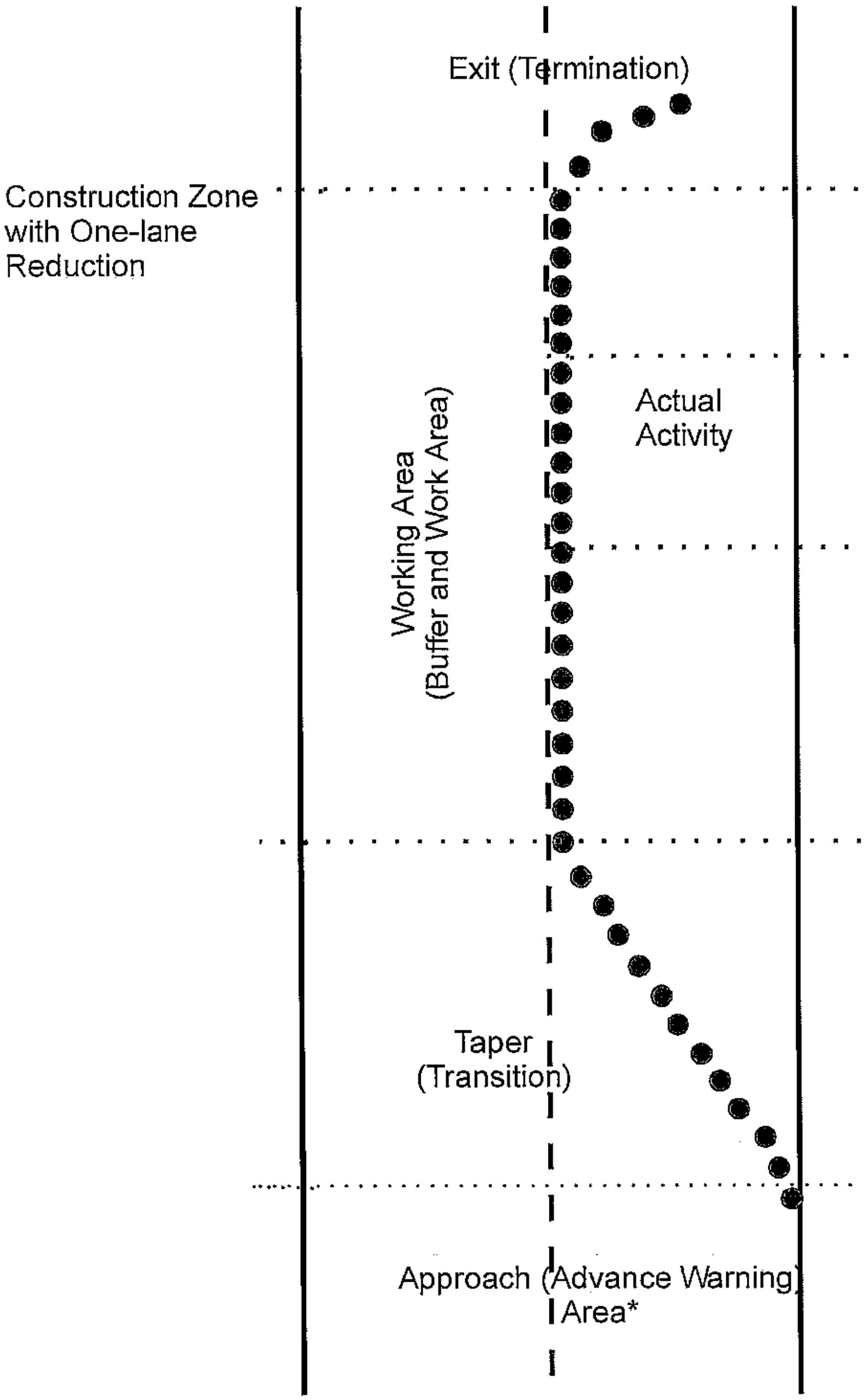
### Introduction

Traffic control devices (TCD) in workzones are intended to provide sufficient guidance to motorists to help prevent collisions, especially with construction operations. Based on the study of their use in Illinois, they appear to be meeting this objective. However, what has been discovered in assessing workzone traffic control and crashes is that collisions occur more frequently than reports show and in ways not necessarily addressed in previous studies. For the most part, the layout of workzones and use of (TCD) within the actual construction area require no changes. They are protecting the workers from the motorists. What leads to collisions inside the construction area are reduced lane widths and lack of adequate escape, especially on limited access roadways. As a result, the most frequent type of collision is rear-end often caused because drivers stop or suddenly slow, and the following drivers are following too close. Outside the construction area, the problem appears related to poor driving behavior and need for some improved guidance for motorists especially within the merge areas. Outside the working area, changes to the layout are recommended.

### Definitions

The traffic control systems in construction workzones typically comprise a set of elements intended to manage traffic flow on the approach and within the actual area of construction. These elements are classified by location in the workzone: advance warning area, transition area, buffer space, work area, termination area. Figure 1 depicts those areas. The **advance warning or approach** area starts where the first information about the type of work at the workzone is given to drivers. Normally, drivers are given information about the condition of the roadway ahead and the actions required to travel safely through the workzone. For example, drivers may be warned to adjust their speed and to merge for a safe path through the workzone area. Inside the **transition area**, which includes a **taper**, the traffic is channelized using a variety of traffic control devices. Transitions may include lane shifts or narrowing, merging, and crossovers to two-way travel. The **work area** includes the **buffer area** which is between the transition and actual work or construction areas and provides a margin of safety for both drivers and workers when a vehicle fails to negotiate the transition area properly. It also includes the portion of the road where construction occurs and is exclusively reserved to workers and equipment. Finally, the **termination area or exit** is the roadway downstream from the work area where traffic is channelized back to the normal traffic lanes. This report will use the terms: approach, taper, working area, and exit to describe the four zones.

**Figure 1**
**Sections of the Construction Zone**




*Note: the advance area can vary in length depending upon traffic, but always should include the 1/2 mile preceding the work area.

## Purpose of the Study

The investigation of traffic controls used in workzones was designed to identify how the traffic control plan (layout for traffic operations in workzones) and traffic control devices affect driving and traffic safety. Specific objectives included:

- determining the typical locations of and conditions under which motor vehicle crashes occur at Illinois roadway construction locations.
- reviewing the characteristics of typical IDOT workzone traffic control plans and, based on historical and current crash data, to identify the factors that may contribute to the occurrence of crashes in construction areas.
- developing statistical models that relate workzone crashes with the various elements of traffic control and assess their statistical significance.
- recommending changes in the design of traffic control systems which would improve safety in the zones, including costs of these changes.

To accomplish these objectives the project was divided into three tasks: a) identify what is known about the relationship between traffic controls and traffic control plan in workzones and crashes, b) gain a better understanding of these elements with motorist behavior through onsite observations, and c) recommend changes in traffic management that could help reduce crashes. Historic crash data was crucial to the project. Analysis of these data and the literature provided the basis for planning site selection and conducting observations.

## Review of Project Tasks

The proposed project was divided into three tasks. Each task was designed to use what was learned from the previous one. This section addresses each of the tasks, its approach, and its outcomes.

### Task A - Comprehensive Review of Workzone Crashes

Task A was designed to understand what was happening in workzones based on the use of historic data. It had two primary parts: review of other research and review of Illinois crash reporting. Five sub-tasks were identified.

A.1. Literature Review. This review of the literature on workzone safety provided some important elements which would bear investigation. Specifically, previous research had suggested that workzone crashes were more severe and happened more frequently than crashes at the same locations when construction was not present. They were speed related, and principally involved in a rear-end collision. What was missing from the research was an examination of crash patterns and driver behavior over the entire extent of the workzone from the approach through the exit; most literature concentrated on the working area itself. The literature review is Chapter 2.

A.2. Assess Crash Data. Crash data from the Illinois Department of Transportation (IDOT) crash database would be used to determine the patterns of crashes in Illinois and to model relationships between traffic control devices (TCD) and crashes. Both data representing crashes in workzones and all crashes were needed for the analysis. In this manner, the analysis would determine the degree to which workzone crashes were over- or under-represented in workzones. What was discovered was the workzone crash data under-reported the true crash picture. As a result, initial conclusions drawn from the abstracted data were changed once all workzone crashes were used. Chapter 3 shows the results of the analysis.

A.3. Technical Review Panel and Selection of Sites. Once the analysis of historic data was completed, the project team was scheduled to meet with the Technical Review Panel to select construction sites for observation and specific crash investigation. Crash data were needed to help determine what classes of workzone should be chosen for investigation, aspects of workzone traffic control, and crash patterns. This meeting occurred after the 1994 and 1995 crash data became available in mid-November 1998. By that time, observations already had occurred at selected sites. More were added as a result of the Panel meeting.

A.4. Enhanced Statistical Analysis. This sub-task was designed to identify relationships between workzone elements (traffic control plans (TCP), layouts, and the TCD's) and elements of the crash (especially manners and locations of collisions). The results were limited by two factors. First, workzone plans generally represented the standard traffic control plans without changes recorded. Second, crash locations were not that accurate, and crashes outside the working area generally were missing. This precluded overlaying the crashes on the entire workzone. However, analysis was possible and the findings are reported in Chapter 6.

A.5. Summary of Literature and Findings. Two interim reports were produced for Task A. Their content appears in this report.

## Task B - Monitor Specific Sites

Task B of the proposal called for seven specific activities related to the selection and assessment of workzone traffic control device effectiveness within those zones.

B.1. View Selected Sites. The purpose of this sub-task was to gather data about the selected sites to serve for more extensive observations including traffic monitoring observations of driver behavior. Five sites were visited in 1998. Two sites were rural Interstate roadways, two rural state numbered routes, and one a suburban limited access roadway. Two sites were added in 1999, an urban arterial roadway and an urban interstate.

For the sites chosen, members of the team visited the sites, examined plans, and held discussions with the resident engineers. Commentary appears in Chapter 7. Because previous research on workzones generally had ignored the approach and taper (also called approach area and transition), the project team turned its attention to this area. Thus, investigation centered on how workzone traffic controls affected driver behavior with special emphasis on queuing (which in turn reflects increased congestion and the increased likelihood of crashes).

B.2. Implement Comprehensive Police Crash Reporting. Specific attention given to crash reporting at selected sites and the inclusion of a supplemental report was designed to provide better information about crashes than normally accompanies a police crash report. The Illinois State Police (ISP) Commanders in the districts covering the sites, the Lake County Sheriff's Department which was responsible for IL 120, and the Northbrook Police Department for IL 68 cooperated in providing a copy of all crash reports taken in the construction area after the date their assistance was requested. These reports included a supplemental form requesting officer opinions regarding causes which would not have appeared on the Illinois Police Crash Report (PCR). One of the key findings was that more than 40% of all crashes associated with a workzone occurred outside the actual construction area. Chapter 5 carries the analysis derived from this reporting.

B.3. Onsite Observations of Driver Behavior. At each site, videotaping was scheduled to learn more about how traffic operated in a construction zone. Most of the attention was directed to the approach and taper. Although the plans had been to videotape each site during different periods of the day, with the exception of IL 120 in Gurnee, there were no real differences in daily traffic flow. As a result, filming done at 1600 hours, for example, showed traffic flows similar to those observed earlier.

In addition to taping drivers entering the workzone, views from the driver's perspective were included for both sites viewed in 1999, I-80 in Joliet and IL 68 in Northbrook. These driver perspectives show the placement of warning signs at a distance of one mile with more frequent signs advising lane closure.

The research team also had an opportunity to film a merge site from the top of an 8-story building. This filming was done specifically to observe and classify merging behavior. It occurred on the Eden's Spur, I-94 in Deerfield. A detailed study of the traffic control plan and devices was not appropriate here because the merge area was at a location approximately one half mile beyond the toll booth and did not represent a true picture of vehicles approaching a construction zone on a multi-lane roadway. It did however, represent how drivers behave when merging into traffic, especially when a queue had formed. The behaviors observed in this filming, as well as at the other sites, provide the basis for discussions in Chapter 8. A videotape containing the tapes from all sessions was submitted separately.

B.4. Measure Traffic Activity. The intention was to use automated equipment to measure volumes and speeds in the workzones, comparing the values before and after work began. However, except for several radar-based speed studies along IL 120, further data could not be gathered. Traffic analyzer equipment purchased proved defective and could not be repaired during the construction season. New equipment allowed measurement at the two sites selected in 1999, but the new equipment became available only after construction began. There was no "before" measurements. The 1999 studies appear in Chapter 8.

B.5. Overlay Crashes on Site Plans. Plotting the location of crashes on the construction layouts was supposed to provide a means of identifying how the crashes related to the TCP and placement of TCD's. This process could not be done with historic data. First, not all crashes occurring in workzones are coded as "construction zone." Second, even properly coded ones often lack a reference point (milepost) sufficiently adequate to place the crash on a layout. Chapter 6 attempted to analyze the relationship between TCD's in general and historic workzone crashes.

Another element which reduced the usefulness of this proposed effort was that construction plans rarely incorporate changes made to the layout. While these data may be available in resident engineer (RE) notes and diary, they do not appear on the plans. More importantly, changes may occur frequently, even on a temporary basis daily, during the construction. What would be a more practical approach would be for the RE to identify the location of each crash on the plan and add notes relating to possible causal factors. A process model for doing this task appears in Chapter 9.

B.6. Enhanced Statistical Model. The purpose of this sub-task was to enhance the initial analyses (Task A.4) given data collected during the on-site visits. Instead, some of the effort expected on this task was combined with Task A.4 and the findings included in Chapter 6.

B.7. Report of Task B. The report from Task B was provided, and its findings appear in several chapters of this final report.

## Task C - Recommendations for Changes and Final Report

This final report provides a number of important recommendations regarding workzone operation, as well as information gathering and use. It also addresses some issues where testing of changes is recommended.

## Key Findings and Structure of the Report

Several important findings arose from the study. Crashes are significantly under-reported on the state database (discussed in detail in Chapter 2). When taking into account the under-reporting, with the exception of increases in certain types of collision such as rear-end, the workzone crashes are no more severe (in terms of injury) than crashes occurring outside such zones. Moreover, crashes with pedestrians (which includes workers) appear no more likely than in locations without workzones. Finally, crashes reported as "workzone" are unlikely to include portions of the workzone away from the actual construction area.

A second key finding is that a process needs to be implemented (final chapter) in which the RE plays a more important role in the workzone planning and ongoing safety. The RE should be one of those responsible for evaluating the initial TCP. During the construction, the RE needs to be reviewing safety elements, especially crashes, as they occur and making changes to the plans based on these reviews.

Finally, the approach to and transition into the workzone appears to generate greater danger especially to motorists than has been recorded in previous research (Chapters 4 and 5). Specific attention needs to be given to traffic movement and enforcement in the approach and transition.

This report addresses the stages of the research starting with the literature search, analysis of historic crash data, and assessment of onsite observations and measures. It finishes with a series of recommendations and provides a model for workzone traffic control improvement. Most important in these recommendations is that the Illinois Department of Transportation (IDOT) resident engineers (RE) and supervisors be more interactive with the design of the traffic control plan by monitoring its effect on motorists' behavior and with crashes when they occur.

Chapter 2 provides an overview of the literature. Following the literature review is an analysis of workzone crashes based on data available from the Illinois Department of Transportation crash database for the years 1994 and 1995. With the discovery of under-reporting of workzone crashes, a need arose to determine the effects of this deficiency on interpretations of the crash data. Chapter 4 describes the results of this investigation.

Supporting the use of historical reports was an attempt to obtain current crash reports with added information about contributing conditions. The supplemental reporting became the basis for Chapter 5. Statistical analysis of workzone crashes and relationship to construction plans appears in Chapter 6. Findings from the onsite visits are contained in Chapter 7 which also reflects on the results of videotaping done during the onsite visits. Chapter 8 presents an analysis of driver behavior around workzones, especially in the approach and taper. Finally, recommendations and a process model for workzone traffic controls conclude the report in Chapter 9.

# 2. Literature Review

This chapter is divided in two major sections: state-of-the-practice on traffic control systems applied by most state and local governments, and an overview of the approaches proposed in the literature to improve workzone safety and introduced techniques to reduce the workzone crash rates. Shortcomings of the existing approaches are identified and the need for further research are established.

## State-of-the-Practice

### Planning

Construction zones differ from maintenance or utility zones because they are of longer duration and cause extended disruption to normal traffic conditions. During planning stages of the workzone, planners need to consider the geometrical characteristics of the roadway, the average daily volume, the period of work, the number of lanes closed to help define the most appropriate traffic control devices and traffic control strategies to be used. Selection of control strategies follow a systematic evaluation of its likely impacts. Typically, the most effective strategy has a significantly lesser impact than other alternative strategies. Benefit/cost analysis and cost-effectiveness evaluation are also used to assess the impact of the control strategies. Dudek, *et al.* (1988) proposed an approach to estimate road user costs for alternative traffic control strategies on four-lane divided roadways.

Dixon, *et al.* (1996) focused on estimating capacity values in freeway workzones by evaluating the reduction of unidirectional, multiple lanes to a single lane (or two), and crossover closure type to determine the number of open lanes required during the construction, adequate construction schedule and other traffic control tasks. Dixon also identifies a relationship between the intensity of work activity and capacity reduction. Sites with heavy work activity have more severe queue build up next to the work area than at the end of the transition. To improve workzone capacity, the literature recommends planners to temporarily make use of shoulders as travel lanes, modifying intersection signal timing, encouraging traffic to divert to alternative routes, and closing the entrance ramp within the workzone. Examples include the Edens Expressway in Chicago or the Gulf freeway in Houston (FHWA, 1988).

### Traffic Control Plans

Traffic control plans (TCP) show the layout and type of traffic control devices to be used in a workzone as well as information about the type of workzone to be used in each phase of the work. For instance, the TCP may include scaled drawings of the control zone, a list of devices selected for installation, specifications of special manpower needs such as flaggers, copies of permits, phone numbers of official contacts, scaled drawings of construction stages, including detours, schedules of the construction period (FHWA, 1988). In a report summarizing the corridor traffic management experiences at completed and ongoing construction projects nationwide, Ullman, *et al.* (1989) presents the TCP as one of three components for the freeway construction project.

The literature identified a potential problem with some of the traffic control plans. They may recommend the use of traffic control devices which might be misunderstood by the drivers. In this respect the study by Ogden and Mounce (1991) identifies misunderstood traffic control by motorists. The driver survey was designed to meet the following objectives: to gain information about workzone traffic control and to determine problematic construction traffic control devices with respect to motorist comprehension. The results showed that many drivers are having difficulties understanding the signs.

## Traffic Control Devices

The spacing between the advance warning signs is subject to a number of standards depending on whether the workzone is in a urban area, residential area, or business district. The spacing between signs in a series is required to be 250 feet for urban, residential, or business district with speeds less than 40 mph; 500 feet for urban arterials and rural roads with speeds more than 45 mph; and 1000 feet for expressways and freeways (FHWA, 1988). FHWA also recommends augmenting the advance warning signs with flashing beacons or supplementary flags. In urban areas, the distances should be adjusted adequately to cope with length of city blocks, distance between adjacent intersections, alleys and side streets. In this respect the work of Kacir and Hawkins (1993) identified urban arterial workzone characteristics and developed traffic control guidelines for urban arterial workzones. The study reviewed opinions of traffic engineers and examined workzone traffic control manuals of local agencies. Crash, volume, and travel time data were collected and analyzed to determine trends specific to arterial workzones. The results showed a significant statistical increase in the number of crashes at or near intersections and driveways, and crashes occurring at night. Motorist surveys revealed that drivers are more interested in information such as the length of the workzone, duration of construction and travel delay rather than the type of traffic control devices used which many drivers also reported difficulties in understanding. The results were used to develop guidelines addressing traffic control for urban arterial workzones which are believed to improve safety and traffic flow in arterial workzones.

The TCD used to channelize traffic inside the workzone should minimize the driver's level of confusion under any environmental or lighting condition. For instance, Shepard (1990) investigated vehicle guidance through workzones by evaluating the effectiveness of the steady burn lights presently used on top of the temporary concrete barriers, and the use of closely spaced raised pavement markers. Steady burn lights on temporary concrete barricades were recommended to be replaced with reflectorized panels fabricated with high intensity sheeting, and closely spaced raised pavement markers should be used as a supplement to existing pavement striping in areas where the roadway alignment changes. Ugwoaba (1987) concluded that drivers need the guidance of delineators most when they are confronted with opposing traffic headlight glare. Finally, Homburger (1987) describes field observations of traffic controls and motorists' perception. Recommendations made include more extensive use of variable message signs (mounted on trailers or trucks) with messages specific to the actions motorists are advised to take, and clearer warnings of which lanes or off-ramps are closed at a particular time.

Head-on collision is a common crash type in a two-lane two-way operation (TLTWO). The paper of Rathbone (1991) discusses the advantages of the Moveable Concrete Barrier (MCB) as a separation device. The concrete barriers are moved laterally in little time to open traffic lanes for peak traffic periods and close them immediately after the peak period. The direction of reversible lanes can also be changed between an off-peak and a peak-traffic period. The results showed an improved safety at the site and reduction in the duration of the construction project. Moreover, the MCB was successful in applications which required daily shifts over an extended period of time. Additional traffic control elements are listed in Table 1. The table derives from a composite from a number of sources.

**Table 1**
**Traffic Control Elements***

| Devices | Design | Policy |
|---|---|---|
| Speed monitoring devices<br>Portable speed bump<br>Rumble mat<br>Implement new traffic lights<br><br>Pilot car operation<br>Remote driven vehicle<br>Flaggers equipped with communication devices<br>Flashing Stop/Slow paddle<br><br>Warning signs<br>Warning lights<br>Folding signs<br>Portable sign brackets<br>VMS<br><br>Truck-mounted attenuators<br>Stationary attenuators<br>Ultrasonic detection alarm<br>Infrared intrusion alarm<br><br>Direction indicator barricades<br>Type I, II, III<br>Arrow panels<br>Opposing traffic lane divider w/ Reflective Cylinder, Studs, Glare Screen, Vertical Panel, Top Mounted Reflector, Steady Burn Light, Chevron Arrow, Pavement Marker<br><br>Cones, Tubes<br>Drums, Cylinders<br><br>Pedestrian push button<br>Detectors | Move traffic light to follow alignment<br><br>Large turning radius<br>Lane closure should not cause queue back up for intersections upstream<br><br>Adjacent intersections<br><br>Raised pavement markers<br>Wider shoulders<br>Strategic placement of signs<br>Update timing plans<br>Alignment<br>Delineation<br>Construction zone markers<br>Construction zone tape<br>Concrete barrier w/ reflector<br>Temporary lighting at night<br><br>Taper location<br>Proper length<br>Proper sight distance<br>Greater length at night<br>Closing ramp<br>Workzone type<br>Lane construction<br>Lane closure<br>Shared right-of-way<br>Temporary bypass<br>Intermittent closure<br>Crossover<br>Use of shoulder<br>Detour | Advisory speed<br>Police intervention<br>Construction phasing to minimize the length of arterial under construction at any one time<br>Store equipment after use<br>Relocate bus stops<br>Improve alternate routes before construction<br>Start dates of projects<br>Regular site inspections<br>Information to drivers through TV, radio and others<br>Detailed plans for traffic needs, such as TCP |

*Dudek, *et al.* 1988; FHWA 1988; Garber and Woo 1991; Ugwoaba 1989.

Garber and Woo (1991) introduced a methodology that examines the effectiveness of different combinations of traffic control devices in reducing crash rates at urban workzones. The study aimed to analyze crash characteristics as a function of the type of traffic control devices used at the workzone. The regression model analysis showed that the most effective combination of traffic control devices on multi-lane highways is cones, flashing arrows and flaggers. In addition, for urban, two-lane highways, the most effective combinations were found to be: cones and flaggers, barricades and flaggers, static signs and flaggers.

The study by Graham, *et al.* (1990) presented the results of tests performed on devices in open highway testing, i.e., operating highways. The results were used to develop recommendations for revising training manuals, operation manuals, personnel requirements for devices, and device evaluation guidelines. Other reported efforts have ranked devices that work most effectively. In *Better Roads* (1994), 200 state, county, and city traffic control readers were surveyed. Cones and signs are the most used workzone control devices, with universal acceptance among those replying. In this study, flaggers, cones, and onsite police were ranked most effective traffic management strategies among the most used ones.

**Flagging and Supplemental Control**

Flagging is used at work sites to control traffic flow and protect the workers. The flagger must always be clearly visible from a distance to the approaching traffic to permit proper driver response to the flagging instructions. Usually, an advance sign warns drivers of the flagger's position.

The objectives of proper flagging are to prevent head-on collision in the one-way section and to minimize delays at either end. To coordinate the movement of the traffic, communication links can be established by using visual communication, field telephone, two-way radio, passing flag. In this respect, the study by Burritt and Guenther (1987) presented a comprehensive analysis of traffic operations and safety throughout the Colorado's Glenwood Canyon. The proposed approach for handling traffic would minimize delays and decrease the potential for a complete stoppage in the Canyon. The key elements of the proposed traffic management plan included a pilot car operation, a communication network between the two ends of the workzone, and a systems approach to coordinating all flagging operations. A pilot car is used to guide a platoon of vehicles through the site and can be most effective where the route is particularly hazardous.

Ullman, *et al.* (1987) identified improper flagging techniques and driver misunderstanding of flagger messages that could compromise the safety and effectiveness of the flagger. The data showed that the temporary stop bar and oversized paddle were useful in helping drivers decide when and where to stop in front of the flagger. However, the stop bar and sign paddle had no significant effect on reducing approach speeds or speeds of vehicles directed by the flagger to proceed through the workzone. Supplemental devices might be necessary to complement standard MUTCD traffic control and flagging techniques to ensure drivers understand what actions are expected of them at workzone controlled by flaggers.

Contracts may include a pay item for police to control traffic and/or speed on the route under construction and to control traffic at key intersections on detour routes. Studies made by Benekohal, Kastel, and Suhale (1992) and Dudek, *et al.* (1988) summarize the role of the police in monitoring the speed limit in the workzone area. The results show that the police radar and the police controller were effective in reducing vehicle speeds.

## Workzone Crashes

Crashes usually increase during the time a workzone is in place. However, more emphasis needs to be placed on the types of crashes and how they are reported to and used by the project manager. Finally, interpretation of crash data need to be based on changes in traffic volume at the sites.

A study conducted by Rouphail, *et al.* (1988) compared the crash experience at both long-term and short-term construction before, during, and after freeway construction and maintenance. The evaluation of TCD layout revealed significant discrepancies between standards and practice. In addition, an evaluation of traffic flow and traffic control devices (TCD) layout in terms of adherence to state standards was undertaken for both types of zones. It was found that at long-term sites the crash rate increased during the existence of the workzone site compared to the before period and decreased in the after period. For short-term sites, no changes in rates were observed. In general, devices were placed closer to the lane taper than allowed by standards. Discrepancies were more frequent at the short term sites where an average of two TCDs were missing compared to the one at long-term sites. Moreover, wider variations in warning signs placement were observed at the short-term sites. Finally, sites characterized by short tapers, no arrow boards, and missing signs exhibit higher speed variations in the workzone.

The analysis of a set of crash data should include classifying the crashes and finding which type occurs most frequently. Crashes are most commonly classified by: location, crash type, time of the day, weather, light, and road surface conditions and severity. A classification of these characteristics can be found in Table 2. As with Table 1, this table represents a composite from multiple sources.

Workzone crash data can be used by a project manager to identify traffic control deficiencies through a systematic procedure of data collection. The process can be used both for taking immediate corrective actions and for developing a database for future analysis. The process includes inspection procedures, crash data collection, data analysis, corrective actions, and statewide summaries. Studies that have evaluated the identification process and/or the use of this data is detailed in the work of Nemeth and Rathi (1983), Hall and Lorentz (1989), Pigman (1990), Nemeth and Ha (1995), and Wang, *et al.* (1996).

A procedure for notification should be used to collect the details of each workzone traffic crash to determine if workzone operations and traffic controls contributed to the crash. The goal of the notification is to have police learn about and investigate all reportable workzone crashes and to have the project manager aware of all crashes occurring within the project limits (FHWA, 1988). It will include the police officer's diagram showing the paths of the vehicles inside the workzone and a narrative description would indicate the role played by the work activity and the traffic control devices at the workzone.

Traffic volume data are needed when analyzing workzone safety and operational problems. Average Daily Traffic (ADT) counts are used to compute crash rates, and the hourly counts will help schedule construction outside the peak hours. Additional traffic flow patterns can be observed from a position along the shoulder of the roadway by video taping the vehicles over a period of time.

## Assessing the Impact of Control Strategies to Reduce Crash Rates

A significant amount of research has been conducted in the general area of traffic control and safety associated with workzones. This section formulates recommendations based on information found in these references.

The literature put great emphasis on delineation inside the workzone area. Ugwoaba (1989) recommended the use of a modular glare screen system on top of a temporary concrete barrier to reduce headlight glare and the ability of motorists to observe work activities. In addition, construction zone markers and road tape can be respectively used for traffic lanes in high-volume, high-speed roadways especially where traffic lanes frequently must be changed and the roadway is not to be repaved.

**Table 2**
**Contributing Factors and Crash Factors for Workzones**

| Contributing Factors | | Crash Type | Crash Severity |
|---|---|---|---|
| **Driver Error**<br>· Inattention<br>· Failure to yield<br>· Improper speed<br>· Following Closely<br>· Cutting Off<br>· Braking, Stopping<br>· Alcohol<br>· Asleep | **Weather Conditions**<br>· Clear<br>· Raining<br>· Snowing<br>· Ice | · Head-On<br>· Rear-End<br>· Backing<br>· Side-Swipe (Meeting/Passing)<br>· Angle<br>· Parked vehicle<br>· Pedestrian<br>· Animal<br>· Train<br>· Pedacycle<br>· Fixed object<br>· Fall from In-vehicle<br>· Overturning | · Fatal<br>· Injury<br>· PDO |
| **Road/Traffic Characteristics**<br>· Curve<br>· Straight<br>· Grade<br>· Number of lanes | **Vehicle Characteristics**<br>· Volume<br>· % of trucks<br>· % RV<br>· Pedestrians | | |
| **Workzone Type**<br>Type and Incident Location<br>· Crossover<br>· TLTWO<br>· Partial Lane Closure<br>· Intersection<br>· Advance Zone<br>· Taper<br><br>Surrounding Geometry<br>· On/Off ramp at work<br>· Transition On/Off ramp<br>· On/Off Ramp prior | **Work Area**<br>· Lane closure or buffer area<br>· Construction area<br>· Heavy, moderate, light operations<br>· Lateral distance to work activity<br>· # lanes open<br>· Capacity reduction at transition and activity area | | |

* see Garber and Woo 1991, Hargroves, *et al.* 1980, Graham, *et al.* 1978, and Sorock, *et al.* 1996.

Typically, partial lane closure and crossover are the most commonly used lane closures strategies. Pal and Sinha (1996) discuss the relative safety effect of the design of each of these strategies showing that under varying conditions one might be more effective than another at reducing crashes, but that no one plan was the most effective.

A number of studies have suggested using variable message signs (VMS) at work sites on high speed, high volume roadways. The VMS can be used as a device to encourage merging further upstream of the beginning of the workzone area or to reduce the speed. Garber and Surbhi (1985) evaluated the effectiveness of the VMS with a radar unit in reducing speeds at workzones. Four VMS messages designed to warn drivers that their speed exceeded the maximum safe speed were tested at seven workzones on two interstate highways in Virginia. The results indicate that the VMS with radar significantly reduced the speeds of speeding drivers.

Further reported efforts in determining the speed limit inside the construction area is the work of Graham, *et al.* (1993) who developed a uniform procedure for determining workzone speed limits. The study included interviews of state highway engineers to discuss current workzone speed limit procedures and guidelines, and interviews of motorists to determine their attitudes concerning workzone speed limits. The data collection gathered vehicle speeds, traffic crashes, and traffic conflicts in workzones. The study showed that drivers reduced their speed on an average by 5 mph where no speed limit reduction was specified. Conversely, when the speed limit was reduced by more than 10 mph the compliance percentage of the drivers was the least. They concluded that in general, workzone speed limit reductions should be avoided whenever possible, particularly where all work activities are located in shoulder or roadside areas and in workzones where no work activities are underway.

Recent research has concentrated on the development of simulation-based evaluation of the impact of the workzone on the arterial traffic. In Rouphail, *et al.* (1988), a computer-based methodology evaluated traffic control systems at arterial street lane closure in the vicinity of signalized intersections. More specific objectives were to develop a microscopic computer simulation model of traffic flow at arterial street lane closures and to derive a series of system measures of performance as an output of the model. Delay, fuel consumption, and queue build-up were used as the measures of effectiveness in validating the model. Other efforts, such as the work of Faghri and Demetsky (1988) have concentrated on the development of a prototype knowledge-based expert system (KBES).

Ullman (1996) explored how natural diversion affects traffic volumes using the exit and entrance ramps upstream of lane closures and the interrelationships between the freeway and frontage road operating conditions that develop at a closure. Traffic queues were observed very quickly becoming almost stationary. The reductions in entrance ramp volumes both upstream of the freeway queue and within limits of queuing, as well as changes in exit ramp volumes within the queue are the contributing factors to the stabilization of the rate of queue growth. This model along with those from other researchers appear in Table 3.

Finally, the literature focuses on efforts made to enhance pedestrians and workers safety. The work of Graham, *et al.* (1990) develops new and more effective ways to protect highway maintenance workers from the dangers of nearby traffic. The two most critical problems are

**Table 3**
**Models Used for Workzone Traffic Operations**

| Authors | Model | Dependent Variables | Independent Variables | Data Collected | Functional Relationship |
|---|---|---|---|---|---|
| ***Capacity*** | | | | | |
| Ullman, 1987 *Queuing and Natural Diversion at short-term freeway workzone lane closures* | Linear Regression. Shock wave analysis. | % reduction in freeway entering volume | · Distance to queue<br>· Speed in queue | · Average freeway volume<br>· Road travel times in order to estimate delays.<br>· Propagation of queuing over time and upstream from lane closure. | %Reduction = $a_1$- $a_2$ Dist. to Queue<br><br>%Reduction = $a_1$- $a_2$ Speed in Queue |
| Dixon, Hummer, Lorscheider, 1996 *Capacity for North Carolina freeway workzones* | Frequency analysis | · Capacity reduction<br>· Queue duration | Various scenarios of lane closures. | · Work operation<br>· Road geometry<br>· Weather and light conditions<br>· Capacity analysis: Traffic distribution, type of vehicle and other. | |
| ***Crashes*** | | | | | |
| Pal and Sinha, 1996 *An analysis of crash experience at interstate workzones in Indiana* | · Non-Bayesian: Before and after study with a comparison group<br>· Negative Binomial.<br>· Poisson.<br>· Normal | Crash rates(CR) | · Various scenarios of lane closures.<br>· Duration of project<br>· Interaction b/w traffic and workzone length | · Fatal, non-fatal injuries<br>· Property damage<br>· Average daily traffic | Log(CR) = $a_1$+ $a_2$ DP + $a_3$TVL |
| Garber and Woo, 1991 *Effectiveness of traffic control devices in reducing crash rates at urban workzones* | Regression models | Crash rates (DACR) | · Prior crash rate (BACR)<br>· Combination of control devices (CONDEV) | · Duration of project<br>· Average daily traffic<br>· Crash data<br>· Devices used | DACR = $a_1$+ $a_2$ BACR +$a_3$CONDEV |
| ***Speed control*** | | | | | |
| Noel, Dudek, Pendleton, Sabra, 1989 *Speed control through freeway workzones: Techniques evaluation* | Ranking techniques using PC-SAS | % reduction in speed | · MUTCD flagging<br>· Innovative flagging<br>· Stationary police cruiser<br>· Uniformed police traffic controller | Speed readings with respect to lane closure | |

traffic hitting the rear of maintenance vehicles, and hitting pedestrian maintenance workers. A snowplow and salt spreader truck-mounted attenuators, lighting devices for improved visibility of maintenance vehicles, and robots for mobile advance warning were conceived to help reduce occurrences of traffic hitting maintenance vehicles. For traffic hitting pedestrian workers countermeasures included: mobile barriers and crash cushions, electronic warning devices for workers, and portable rumble mats to alert errant drivers. Also, Noel (1989) looked into practices for controlling and protecting pedestrians in workzones. The findings and recommendations are based on interviews, literature review, and field observations of highway, building construction, and maintenance projects in several cities. These recommendations suggested mid-block sidewalk closure, corner closure of sidewalk, crosswalk closure, fencing near intersection, and canopies to protect pedestrians from overhead work. The study also identifies changes to be made for standards listed in the MUTCD.

### Summary of Statistics in the Literature

This section summarizes some of the statistical findings of workzone studies. Table 4 shows the changes in crash experiences during construction found in seven studies. Only in New Mexico were there no changes in either fatalities or injury crashes; the remainder showed increases. Crash rates always increased (with the exception of some sites examined by Midwest Research where negative changes occurred). Table 5, also from Nemeth and Ha (1995) shows the distribution of crashes in the various states studied by location within the zone. The studies show an increase in the crash rate and in severity at the construction sites. However some studies such as those reported in Nemeth and Ha have presented inconsistent findings with lesser severe crashes.

Table 6 compares frequency and percent of crashes in workzones as gathered by Nemeth and Ha, Hall and Lorenz (1989) and Sorock, *et al.* (1996). In some cases, a large difference in percentage is found.

Finally, Table 7 shows the results of driver perception studies reported in *Better Roads* (1994) regarding "effectiveness" of differing devices and traffic control methods. These were, however, expressed opinions and were not supported by research studies.

This chapter has reviewed the state-of-the-practice on traffic control systems as well as approaches proposed to assess the impact of the control strategies. The studies confirm a significant increase of crash rates when workzones are in place. Generally, the drivers appear to have difficulties adjusting to the roadway conditions.

**Table 4**
**Crash Experience During Construction Period**

| Study | Study Site | % Change in Crash Rate | Severity | |
|---|---|---|---|---|
| | | | Fatal | Injury |
| California * | California | +21.4 to +7.0 | Higher | NA |
| Virginia * | Virginia | +119.0 | Higher | Higher |
| Georgia * | Georgia | +61.3 | Higher | Higher |
| Midwest Research Institute* | Colorado<br>Georgia<br>Michigan<br>Minnesota<br>Ohio<br>New York<br>Washington | +6.8<br>(The range varied from –3.4% to +37.6% by state) | NA | NA |
| Ohio* | Ohio | +7.0 | Higher | NA |
| Rouphail* | Unknown | +88.0 | NA | NA |
| New Mexico* | New Mexico | +33.0 (Rural Interstate)<br>+17.0 (Federal-Aid Primary)<br>+23.0 (Federal-Aid Secondary) | Same | Same |

* Adapted from the work of Nemeth and Ha (1995)

**Table 5**
**Distribution of Crashes by Location**

| Study | Location | | | | | | |
|---|---|---|---|---|---|---|---|
| | Advance Zone | Taper | Work Area | Ramp | Crossover | TLTWO | Other (Intersections) |
| Virginia* | 12.7% | 13.3% | 44.7% | 0.0% | 0.0% | 0.0% | 29.3% |
| Ohio Rural* | 15.9% | 22.5% | 28.3% | 3.3% | 0.0% | 0.0% | 30.0% |
| Kentucky* | 5.6% | 7.9% | 54.1% | 0.0% | 0.0% | 0.0% | 32.4% |
| Ohio Turnpike* | 6.5% | 9.2% | 23.2% | 0.0% | 34.1% | 22.2% | 4.8% |

* Adapted from the work of Nemeth and Ha (1995)

**Table 6**
**Distribution of Crash by Types**

| | Nemeth and Ha (1995) | | | | Hall and Lorentz (1989) | | | | Sorock, Ranney, and Lehto (1996) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Crash Type** | **Before** | | **During** | | **Before** | | **During** | | **Observed Crashes** | |
| Head-on | 9 | 2.3% | 7 | 0.8% | NA | | | | NA | |
| Rear-End | 68 | 17.8% | 164 | 20.2% | 47 | 9.4% | 87 | 13.7% | 1,142 | 31.0% |
| Backing | 1 | 0.2% | 8 | 0.9% | NA | | | | 177 | 4.8% |
| Side-Swipe (Meeting) | 1 | 0.2% | 1 | 0.1% | 41 | 8.2% | 43 | 6.8% | 57 | 1.5% |
| Side-Swipe (Passing) | 59 | 15.4% | 136 | 16.8% | NA | | | | NA | |
| Angle | 19 | 4.9% | 39 | 4.8% | NA | | | | NA | |
| Parked Motor Vehicle | 7 | 1.8% | 21 | 2.5% | NA | | | | NA | |
| Pedestrian | 2 | 0.5% | 6 | 0.7% | NA | | | | NA | |
| Animal | 35 | 9.1% | 30 | 3.7% | NA | | | | NA | |
| Fixed-Object | 107 | 27.9% | 201 | 24.8% | 83 | 16.6% | 114 | 18.0% | 413 | 11.2% |
| Other-Object | 13 | 3.4% | 106 | 13% | NA | | | | 257 | 7.0% |
| Fall From or In Vehicle | 1 | 0.2% | 0 | 0% | NA | | | | NA | |
| Overturning | 10 | 2.6% | 24 | 2.9% | 20 | 4.0% | 21 | 3.3% | 16 | 0.4% |
| Other Non-Collision | 51 | 13.3% | 67 | 8.2% | 171 | 34.3% | 208 | 33.0% | NA | |
| Not Specified | – | – | – | – | 137 | 27.5% | 158 | 25.0% | 1624 | 44.1% |
| Total | 383 | 100% | 810 | 100% | 499 | 100% | 631 | 100% | 3,686 | 100% |

**Table 7**
**Description of Effectiveness and Utilization of Traffic Control Devices**

| Devices/Methods | Most Effective (% who call it most effective) | Most Used (% of depts. that use) |
|---|---|---|
| Flashing arrow boards | 25.4% | 83.6% |
| Flaggers | 11.9% | 91.0% |
| Cones | 10.4% | 100% |
| On-site police | 8.9% | 49.1% |
| Electronic message signs | 5.9% | 46.3% |
| Truck-mounted attenuators | 3.1% | NA |
| Portable traffic signs | 2.9% | NA |
| Stationary attenuators | 1.7% | NA |
| Drums | 1.3% | NA |
| Signs | NA | 100% |
| Barriers | NA | 82.1% |
| Temporary markings | NA | 59.7% |

Data from *Better Roads* (1994)

## 3. An Analysis of Workzone Crashes Derived from Illinois Crash Data

### Use of Crash Reports

This chapter, based on vehicle crash data abstracted from the State of Illinois crash data files, identifies how the presence of workzones affects crashes. Typically, a workzone crash is the result of interaction among three elements: the driver, the vehicle, and the environment, especially the workzone characteristics. The police crash report (PCR) is designed to collect data pertaining to all three elements. However, as discussed in the literature (see Ibrahim and Silcock 1992, O'Day 1991, Hauer and Hakkert 1988 as examples), this report generally contains relatively exact data only about elements which the officer can observe directly. There is less accuracy and precision about items that require his or her further investigation, and often the report contains highly imprecise data when the officer's opinion is solicited. For example, the crash reports, especially in a property-damage-only (PDO) crash, may not show contributing circumstances, drivers' prior actions, or sequences of events.

Citations issued at the scene may provide some information about the events prior to the crash. However, since many Illinois police agencies require a citation to be issued at every crash, the law referenced may simply be a "convenience", e.g., "driving too fast to avoid a crash."[1] Only in the event of a serious injury or fatal crash may the police report reflect the cause as a result of a thorough investigation. Because the police crash reports (PCR) and citations do not include highly accurate data, conclusions drawn as a result of using those reports should be considered preliminary.

For the analyses, records were received from the Illinois Department of Transportation (IDOT) database covering all crashes coded as workzone in 1994 and 1995.[2] The IDOT database provided 7,749 workzone crashes in 1994 and 6,206 crashes in 1995. In addition to the workzone crashes, IDOT also made available the entire database covering all vehicle crashes for 1994 through 1996. Although only the crashes coded as "workzone" or "non-workzone" on the IDOT files were used for this Chapter, further research using these same records suggests that those crashes coded as "workzone" may represent only a fraction of all crashes that occurred within a construction zone (see Chapter 4). Data from 1996 also could not be used directly for comparative purposes because IDOT changed the basis for abstracting the data from police crash report, reducing the number of crashes in the database by approximately 65 percent.[3]

---

1 This is the most frequent citation issued by police to the "at-fault" motorists in rear-end collisions rather than "following to closely" which more likely may be the case (for example, as found in reviewing the crash report database from Chicago which shows both manner of collision and citation).

2 The Roadway Deficiency element (RDEF) is coded as a 2 for "construction zone." Codes of 3, 4 and 5, cover other types of workzones. Because they were not related to "construction" which was the basis of the investigation reported here, they were not included as part of the category "workzone" in this analysis.

3 In 1996, IDOT changed to coding only crashes occurring on state maintained routes or resulting in a fatality. This process substantially reduced the number of crashes recorded.

Sections in this chapter examine similarities and differences in crashes between 1994 and 1995, and between workzones and non-workzones to identify the contributing factors. They analyze the characteristics of the crashes, drivers, and vehicles for workzone crashes reported in the IDOT database for 1994 and 1995. Also, one section compares the findings to those from the literature.

### Analysis of the Crashes, Drivers, and Vehicles

#### Information about the Crashes

Severity. As shown in Table 8, workzone crashes occurring both in 1994 and 1995 were more likely to result in an injury than non-workzone crashes (33% compared to 22% in 1994 and 32% compared to 21% in 1995). Property-damage-only (PDO) crashes were less likely to occur in a workzone. Reporting done at selected workzones by police for this research, and where emphasis was placed on reporting all workzone crashes, showed an injury to PDO relationship similar to the crashes coded as "non-workzone." That the supplemental reports covered primarily Interstate roadways may have accounted for part of the differences. Fatalities in workzones occur no more or no less frequently.

**Table 8**
**Severity of Workzone and Non-Workzone Crashes**

| Severity | | 1994 Non-Workzone | 1994 Workzone | 1995 Non-Workzone | 1995 Workzone |
|---|---|---|---|---|---|
| Fatal | Frequency | 1,369 | 26 | 1,376 | 26 |
| | Percent | 0.3% | 0.3% | 0.3% | 0.4% |
| Injury | Frequency | 97,233 | 2,575 | 97,328 | 1,982 |
| | Percent | 21.8% | 33.2% | 21.4% | 31.9% |
| PDO | Frequency | 346,544 | 5,148 | 357,114 | 4,198 |
| | Percent | 77.8% | 66.4% | 78.3% | 67.6% |
| Total | | 445,146 | 7,749 | 455,818 | 6,206 |

Crash severity from the Illinois data also was compared to seven other studies reported in the literature. As shown in Table 9, fatalities and injuries, as a percent of all crashes were higher in most cases. Only in New Mexico were there no differences. The supplemental reports taken in Illinois also showed no increases with injury crashes before and during construction. Only in Illinois and New Mexico did fatalities remain the same. This result may simply arise because the frequencies of fatalities are so low that differences occur by chance, or they could be attributed to efficient and safer traffic control devices introduced since most of the referenced studies have been published and would have been reflected in the Illinois workzones operated in 1994.

**Table 9**
**Severity of Crashes at Construction Sites**
**Before and During Construction**

| Study | Study Site | Severity | |
|---|---|---|---|
| | | **Fatal** | **Injury** |
| California * | California | Higher | NA |
| Virginia * | Virginia | Higher | Higher |
| Georgia * | Georgia | Higher | Higher |
| Midwest Research Institute* | Colorado<br>Georgia<br>Michigan<br>Minnesota<br>Ohio<br>New York<br>Washington | NA | NA |
| Ohio* | Ohio | Higher | NA |
| Rouphail* | Unknown | NA | NA |
| New Mexico* | New Mexico | Same | Same |
| Illinois State Database | Illinois | Same | Higher |
| Special Reporting | Illinois | None | Same |

* Adapted from the work of Nemeth (1983)

Vehicles involved. Table 10 shows the number of vehicles involved in a crash. Workzone crashes were more likely to involve either one, or more than two vehicles. This finding was consistent for both 1994 and 1995, as well as in the supplemental reporting. The increase in the percentage of three or more vehicles involved in a crash during a workzone might result from the shorter headways induced by the reduced capacity through the workzone. Consequently, drivers have less time and distance to react to sudden slowing, and with no escape route crashes involving multiple vehicles could be more likely to happen.

Manner of collision. The most common manner of collision for vehicles within the workzone was a rear-end as shown in Table 11. In 1994, 31% and in 1995, 35% of all crashes (on the average 1 of every 3) occurred in this manner. For a reason similar to that given above for multiple vehicle collisions, vehicles are traveling close together as a result of reduced capacity and have a limited opportunity to stop in time. Next most frequently indicated was "angle/turning." These manners of collision would be most frequent on urban streets under construction where there are many opportunities for such collisions.

**Table 10**
**Number of Vehicles Involved in Crashes**

| Number of Vehicles | | 1994 Non-Workzone | 1994 Workzone | 1995 Non-Workzone | 1995 Workzone |
|---|---|---|---|---|---|
| 1 | Frequency | 77,762 | 1,490 | 83,205 | 1,236 |
| | Percent | 17.5% | 19.2% | 18.3% | 19.9% |
| 2 | Frequency | 335,950 | 5,315 | 339,825 | 4,265 |
| | Percent | 75.5% | 68.6% | 74.6% | 68.7% |
| 3+ | Frequency | 31,434 | 944 | 32,788 | 705 |
| | Percent | 7.1% | 12.2% | 7.2% | 11.4% |
| | Total | 445,146 | 7,749 | 455,818 | 6,206 |

**Table 11**
**Most Common Manner of Collision in Workzones**

| Manner of Collision | 1994 Non-Workzone | 1994 Workzone | 1995 Non-Workzone | 1995 Workzone |
|---|---|---|---|---|
| Rear-end | 17.8% | 31.3% | 26.0% | 34.9% |
| Angle/Turning | 20.8% | 17.9% | 31.0% | 23.6% |
| Object | 15.7% | 11.8% | 22.5% | 17.2% |
| Sideswipe - same dir. | 4.7% | 7.8% | 8.5% | 10.2% |
| Non-collision | 5.2% | 8.2% | 3.3% | 4.6% |
| All Other | 35.8% | 23.1% | 8.7% | 9.5% |

Finally, sideswipe, same direction crashes were slightly over-represented as opposed to those outside the construction areas. Given the increased likelihood of such crashes occurring during merging, especially where four lanes of travel have been reduced to two, this over-representation is expected. Figure 2 depicts all manners of collisions in workzones for 1994 and 1995 combined.

The manners of collision from the Illinois data were compared to some findings in the literature. As Table 12 indicates, the Nemeth and Hall studies showed that rear-end collisions increased in workzones, although not to the same extent as in Illinois. Another substantive difference for Illinois was the high percentage and increase in sideswipe, same-direction collisions. The three studies all show different percentages by type. Further analysis of these data is limited however, because the differences could have arisen from how different states code their manner of collision or from how the authors interpreted the data in their research.

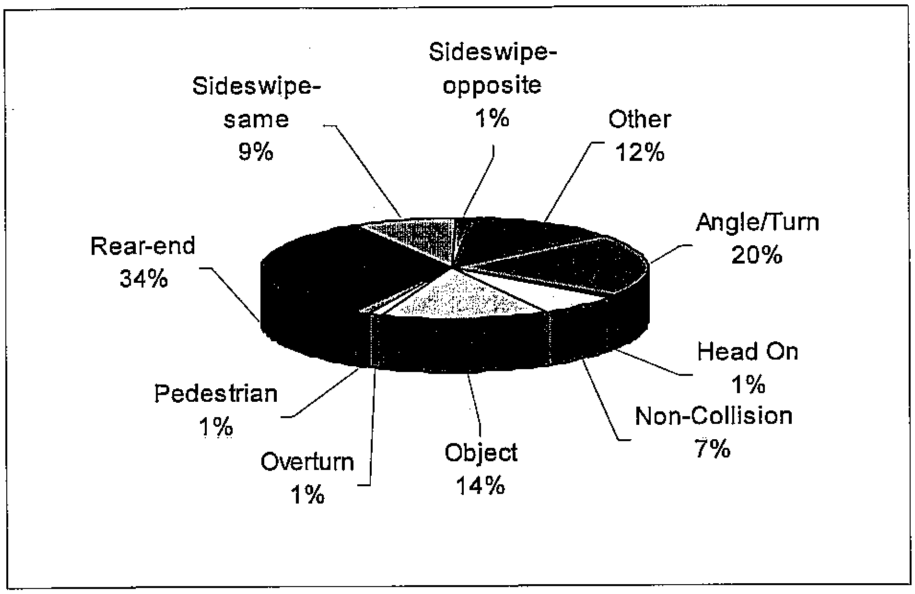



**Figure 2**
**Distribution of 1994 and 1995 Workzone Crashes**

**Table 12**
**Distribution by Crash Types from the Literature**

| Manner of Collision | Nemeth | | Hall | | Illinois | |
|---|---|---|---|---|---|---|
| | Before (%) | During (%) | Before (%) | During (%) | Non-Workzone (%) | Workzone (%) |
| Head-on | 2.3% | 0.8% | NA | 0.0% | 1.1% | 1.0% |
| Rear-end | 17.8% | 20.2% | 9.4% | 13.7% | 21.9% | 32.9% |
| Side-swipe (same) | 0.2% | 0.1% | 8.2% | 6.8% | 6.6% | 8.8% |
| Side-swipe (opposite) | 15.4% | 16.8% | NA | NA | 1.3% | 1.3% |
| Angle | 4.9% | 4.8% | NA | 0.0% | 20.9% | 20.4% |
| Fixed Object | 27.9% | 24.8% | 16.6% | 18.0% | 19.1% | 14.2% |
| All Other / Non Collision | 31.5% | 32.5% | 65.8% | 61.5% | 29.1% | 21.4% |

Day-of-week and time-of-day. Figure 3 depicts the percent of crashes by day of the week for workzones. The IDOT database showed that the largest percentage of workzone crashes occurred on Friday. Commuters' fatigue coupled with traffic congestion are probably contributing factors to the Friday crashes. Crashes for the remaining weekdays were fairly consistent at approximately 14% each day. For the weekend, crashes were substantially lower. However, in part, this may result from construction not occurring on the weekend (and perhaps police not coding the crash as "workzone related"), temporary traffic restrictions eliminated, and fewer vehicles using the workzones (with a lessened opportunity for crashes resulting from the high volumes). Figure 4 displays the crashes by three-hour grouping. Both workzone and non-workzone crashes peak in the late afternoon. However, a lower percentage of workzone crashes take place during those hours than non-workzone crashes.

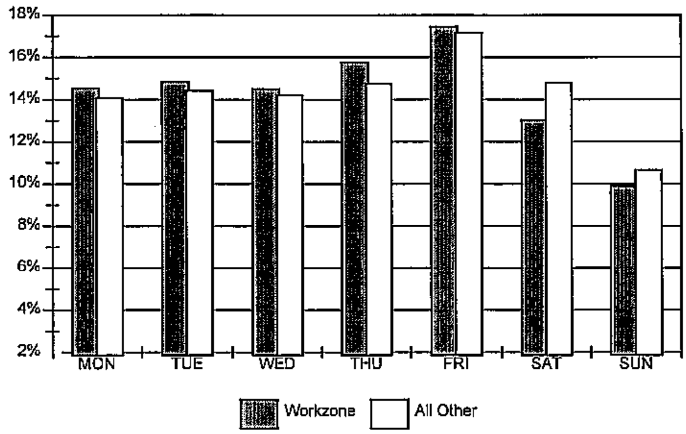



**Figure 3**
**Workzone and Non-Workzone Crashes by Day**
**1994 and 1995**

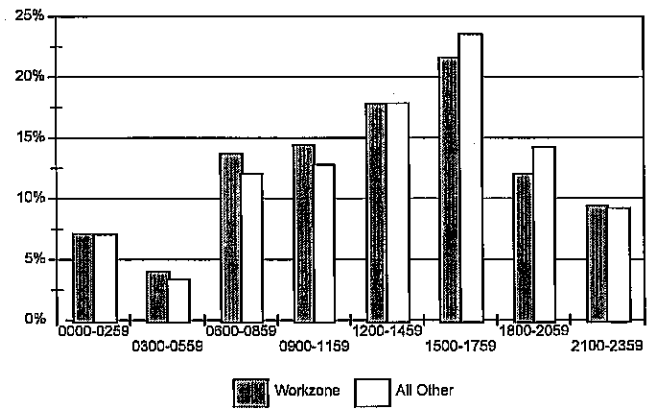



**Figure 4**
**Workzone and Non-Workzone Crashes by Time of Day**
**(1994 and 1995)**

Other factors. The analysis looked into other possible contributing factors such as light conditions, weather and road surface (for cross tabulations of light, weather, and road surface, see Appendix A). Results showed that 83% of workzone crashes occurred in clear weather and 70% during the daylight hours. The road was dry 73% of the time. Corresponding percentages for non-workzones was 78% clear, 66% daylight, and 66% dry. Additionally, 25% of the workzone crashes took place in darkness or on lighted roads as opposed to 29% on all other roads. Chi-square tests showed none of the differences were significant at the 0.05 level. With the exception of crashes in clear weather and dry roads at night, all the other cross tabulations are divided too thinly to determine if certain categories are over- or under-represented.

Workzone crashes were over-represented on urban and rural controlled access roadways, although only 1.5% of all crashes for 1994 and 1995 occurred in workzones. Yet, 4.3% of all crashes on limited access roadway were coded workzone. Moreover, if workzone crashes could be expressed in rates per million vehicle miles, the rates for limited access roadways could be lower than for other types of roadways. However, the state does not collect ADT for workzones, so rates cannot be computed generally.

The next section draws some conclusions about vehicles and drivers based solely on the data for crashes occurring in workzones. These are not compared to all crashes.

## Drivers and Vehicles

Attributes related to the driver. Driver condition and vision were checked as "normal" or "not obstructed" in 86% of the 17,818 vehicle records for 13,955 crashes occurring in 1994 and 1995. The contributing factors appear to be external to the driver and his or her vehicle. This was made clear in the supplemental forms submitted with crash reports in 1998 and 1999. Occasionally the narrative portion of the report can provide additional details related to driver conditions, but such narratives often accompany only reports where severe injuries were present.

Most of the vehicles involved in a crash were of vehicle type (VEHT) "passenger." More than 78% either were coded as "passenger car" or "pickup." The vehicle use element (VEHU) was coded "personal" in 81% of the vehicles reported. The next largest category was "other."

Even more frequently used was a code of "normal" such as "driver condition - normal," "seat-belt used." For example, driver condition was normal and driver vision not obstructed, each 86% of the time, and the two combined accounted for 91% of the drivers recorded. Because of this situation, any additional combinatorial analysis, e.g., driver condition by vehicle type, would have yielded little additional data of value.

Events related to the crash. In approximately 60% of the crashes, the at-fault driver was coded as proceeding straight ahead, slowing, or stopped in traffic. Both actions would have been expected given the high percentage of rear-end and sideswipe, same direction crashes.

In more than three quarters of all crashes, the "at-fault" driver collided with another motor vehicle in traffic. In another 8% of the cases, the driver ran off the roadway. As shown in Table 13, the first event in approximately 76% of all crashes was striking a motor vehicle in traffic. Run-off-the road, striking other than fixed objects (including pedestrians), and fixed objects varied slightly from year to year.[4]

As shown in Table 14, police did not enter a code for driver action (database coded as 0) for approximately one quarter of all crashes. "Too fast for conditions" was the next most frequently coded single contributor followed by "failed to yield" and "followed too closely." One of the problems in coding this element is that it requires the police officers 1) to have sufficient

[4] The typical method of reporting crashes on the Illinois Police Crash Report is to list the "at-fault" driver first.

**Table 13**
**The First (At-Fault) Vehicle, All Workzone Crashes**
**1994 and 1995**

| | Frequency | Percent |
|---|---|---|
| **First Prior Action** | | |
| Straight Ahead | 4,251 | 47.4% |
| Turning | 873 | 9.7% |
| Slow/Stop in Traffic | 1,123 | 12.5% |
| Changing Lanes | 602 | 6.7% |
| Skidding/Control Loss | 929 | 10.4% |
| Other | 1,184 | 13.2% |
| **First Event** | | |
| Ran off the Roadway | 679 | 7.6% |
| Hit a Motor Vehicle in Traffic | 6,792 | 75.8% |
| Hit Other Object | 231 | 2.6% |
| Hit Fixed Object | 352 | 3.9% |
| Other | 908 | 10.1% |
| **First Location** | | |
| Same Direction | 5,195 | 58.0% |
| Opposing Direction | 394 | 4.4% |
| In Intersection | 1,911 | 21.3% |
| Merging Area | 132 | 1.5% |
| Other | 1,330 | 14.8% |
| All Vehicles | 8,962 | 100.0% |

evidence to determine the driver action prior to the crash and 2) to use all of the available evidence from their investigative efforts. Ample evidence exists from the literature (O'Day 1993 for example) that police do not adequately code contributing circumstances. Moreover, Illinois traffic law provides for a citation of convenience in "driving too fast to avoid an accident," which according to 625 ILCS 11/601(a) is "too fast for conditions."

**Table 14**
**Driver Action Prior to the Crash**

| Driver Action | Frequency | Percent |
|---|---|---|
| None | 2,086 | 23.3% |
| Too Fast for Conditions | 1,577 | 17.6% |
| Failed to Yield | 1,407 | 15.7% |
| Followed Too Closely | 1,277 | 14.2% |
| Improper Lane Change | 781 | 8.7% |
| Other | 1,834 | 20.5% |
| Total | 8,962 | 100.0% |

Contributing factors from Illinois crashes were compared to those from the literature. Table 15 shows some of the contributing factors found in the literature. The column heading "unsafe speed" is difficult to interpret. Both Nemeth and Ha (1995) and the supplemental forms from

Illinois in 1998 suggest that the term "unsafe speed" applies to speeds faster than safe for the time and specific location of the crash. Other authors are not clear in their definitions. Nemeth, especially, found no instances in which he could identify that excessive speed (above the limit), at least within the construction area, was related to a collision. The only excessive speed reported on the supplemental forms (and also from one of the ISP reports), occurred in crashes prior to the actual construction. Comparing Illinois experience in 1994 and 1995 to the percentages shown by Sorock, Raney, and Lethro (1996), the excessive speed percentage is almost twice as large. It is somewhat higher for failure to yield, and approaching the same for following too closely. However, Sorock also had the category "driver error" which may have contained the other contributing factors, but they were not specifically stated.

## Crashes Along Selected Segments

Crashes for selected locations under construction were compared to crashes after the construction was completed. In the literature, most comparisons have shown that crashes increase after construction starts and decrease once it is completed. Because of the order in which data were received, a set of workzone segments were selected for 1994 and then compared to what occurred in 1995 after the construction was completed.

**Table 15**
**Contributing Factors to Workzone Crashes**

| | Stated as Contributing Factors or Percentages Given | | | |
|---|---|---|---|---|
| Study | Driver Error | Unsafe Speed | Fail to Yield | Follow Too Close |
| Virginia* | Yes | No | No | No |
| Ohio Rural* | Yes | Yes | Yes | No |
| New Mexico* | Yes | No | No | Yes |
| Kentucky* | Yes | Yes | No | No |
| Ohio Turnpike* | Yes | Yes | No | No |
| Hargroves** | Yes | No | No | No |
| Sorock | 32% | 10% | 15% | 12% |
| Illinois[1] | No[3] | 18% | 16% | 14% |
| Illinois[2] | Yes[3] | 10% | 10% | 8% |

* Adapted from the work of Nemeth (1983)
**Adapted from the work of Rouphail (1988)
[1]From the Illinois Crash Database
[2]From supplemental crash reporting
[3]Not coded as such on the Illinois police crash report, but obtained from the supplemental report

## Process for Selecting Segments

The location of crashes in Illinois are coded by milepost, but the construction plans are based on stations from a marked starting location on the roadway. To equate the mileposts to the construction plans would have required significant effort. Because the comparison of crashes in 1999 was being made between 1994 and 1995 crashes, this also would have required time to retrieve the original construction plans. However, what is important is an answer to the question, were crashes during construction more than crashes after construction was completed for *the same segment and same dates* in the previous year?" The research team decided to select segments of roadways definitely under construction in 1994 and compare those to the same segments when construction was not occurring in 1995. If the segment selected was under construction, the important element is using the same segment after construction is completed.

Examination of the abstracted data from the IDOT files showed that segments could be selected by looking for the first and last milepost along a segment of roadway at which a crash was coded as "construction" (the PCR element RDEF coded as "2"[5]). A secondary step was to examine all crash reports at locations between the extremes. As long as other crashes were coded as "construction" at frequent intervals in this segment, a reasonable presumption was that this was a workzone. The second step was to restrict crashes on the selected segment to those occurring between specific dates. If the first recorded workzone crash occurred on March 10 and the last on November 15, these dates became the assumed starting and ending dates for the project. This process is shown in Table 16. In this table, the first crash that fits the criteria is number 3 at milepost 12.15. The end of the segment is milepost 14.32 for crash number 16. The dates range between April 05 and November 14. Note that crashes numbered 12 and 18 are not included because they lie outside the range.

When an initial sample (representative of the state as a whole) of segments was chosen, and the individual records examined, it became clear that the broad definition had to be modified slightly. The segment in distance was limited to that where crashes coded as construction occurred at least every 0.5 miles and the dates lay between the first date and last dates for such coded crashes.

## Results of the Comparison

When crashes along segments for 1994 where workzones were in place were compared to the same segments in 1995 when construction apparently was completed, in most cases, crashes increased. Although a few segments showed decreases, most increases ranged from nearly approximately 25% to approximately 275%. For the segments selected, the average increase was nearly 200%. Such increases after the work was completed clearly contradicted both expectations, that is workzones are considered a more dangerous location for driving, than what other research had shown. Table 17, extracts a few of the segments from Table 23 in Chapter 4 to demonstrate the problems found. For example, in Boone County along IL 76, crashes more than doubled after the construction was finished. In Cook County, I-94 had a 225% increase. With few exceptions, all the segments which had been chosen as representative of construction throughout the state showed increases. What this finding initially suggested, however, was that crashes were occurring in workzones but not being recorded as such. The next chapter addresses this hypothesis in greater detail.

---

5 The code "2" stands for construction zone. There are additional workzone codes: 3 - maintenance zone, 4 - utility zone, and 5 - workzone unknown; however, those crashes coded with a 2 represent 93.5% of all "workzone" crashes coded with the other codes accounting for 6.5%.

**Table 16**
**Crashes Occurring Along Hypothetical Route 222**
**Displaying Process for Identifying a Workzone**

| Crash No. | Milepost | RDEF | Date | Time |
|---|---|---|---|---|
| 1 | 6.44 | 2 | 6/18/94 | 0615 |
| 2 | 11.92 | 1 | 7/21/94 | 0800 |
| 3 | 12.15 | 2* | 5/30/94 | 1215 |
| 4 | 12.23 | 2* | 4/05/94 | 1220 |
| 5 | 12.56 | 1 | 4/15/94 | 0725 |
| 6 | 12.57 | 2* | 8/21/94 | 0945 |
| 7 | 12.79 | 1 | 11/01/94 | 1115 |
| 8 | 13.01 | 1 | 6/03/94 | 1120 |
| 9 | 13.03 | 2* | 11/14/94 | 1455 |
| 10 | 13.18 | 1 | 11/07/94 | 1450 |
| 11 | 13.45 | 1 | 6/08/94 | 1630 |
| 12 | 13.49 | 1 | 03/03/94 | 1640 |
| 13 | 13.50 | 2* | 5/04/94 | 0940 |
| 14 | 13.91 | 3* | 6/08/94 | 1000 |
| 15 | 14.04 | 1 | 7/08/94 | 1005 |
| 16 | 14.32 | 2* | 5/19/94 | 1125 |
| 17 | 14.39 | 1 | 6/15/94 | 1620 |
| 18 | 18.96 | 1 | 3/18/94 | 0910 |

* The Roadway Deficiency Code, where codes 2 through 5 represent workzones

**Table 17**
**Crashes on Selected Segments**
**Changes from 1994 (Workzone) to 1995 (Non-Workzone)**

| County | Route Number | Mileposts[1] From | Mileposts[1] To | Month From | Month To | Crashes 1994 Workzone | Crashes 1995 No Workzone | Crashes Percent Change 94-95 |
|---|---|---|---|---|---|---|---|---|
| Boone | IL 76 | 3.77 | 16.53 | 6 | 11 | 14 | 29 | 107.1% |
| Cook | US 12 | 9.24 | 11.31 | 4 | 10 | 62 | 233 | 275.8% |
| | IL 43 | 4.61 | 11.55 | 4 | 11 | 69 | 261 | 278.3% |
| | I-94 | 42.66 | 45.90 | 3 | 10 | 16 | 52 | 225.0% |
| | IL 171 | 15.78 | 17.49 | 4 | 11 | 22 | 31 | 40.9% |
| DuPage | IL 59 | 13.62 | 16.42 | 4 | 10 | 50 | 68 | 36.0% |
| Jefferson | I-57 | 80.70 | 96.47 | 5 | 11 | 24 | 64 | 166.7% |
| Sangamon | I-55 | 0.78 | 2.75 | 7 | 9 | 18 | 52 | 188.9% |

[1]Mileposts represent segment from first crash identified as workzone to last one

## Workzone Layout

The proposal for research called for examining individual crash reports, locating them on a layout of the workzone, and providing a more comprehensive assessment of what occurred based on narrative and diagram. This did not prove feasible. In addition to potential under-reporting of crashes, the data abstracted in the IDOT database indicated locations which could not be placed on a specific highway. As an example, Table 18 displays the crash data coded as "workzone" (representing one or more such zones) occurring on I-55 in Sangamon County in 1994. The segment of I-55 within the county runs from milepost 78 through milepost 104. As the Table shows, an exact location of most crashes is indeterminate[6].

**Table 18**
**1994 Workzone Crashes Occurring Along I-55 in Sangamon County**

| Recorded Locations on I-55 To the Nearest Mile | | Recorded Locations That May Refer to the Nearest 1/10th or 1/100th Mile | | Locations That Do Not Correspond to I-55 Mileposts | |
|---|---|---|---|---|---|
| **Mileposts** | **Frequency** | **Mileposts** | **Frequency** | **Mileposts** | **Frequency** |
| 78 | 1 | 832 | 1 | 126 | 1 |
| 82 | 1 | 876 | 1 | 152 | 1 |
| 90 | 1 | 877 | 1 | 154 | 1 |
| 103 | 2 | 878 | 1 | 155 | 1 |
| 104 | 1 | 881 | 1 | 174 | 1 |
| 106 | 1 | 897 | 1 | 275 | 1 |
| Sub Total | 7 | 907 | 3 | 464 | 1 |
| | | 909 | 1 | 525 | 1 |
| | | 911 | 1 | 624 | 1 |
| | | 994 | 1 | 646 | 1 |
| | | 9406 | 1 | Sub Total | 10 |
| | | 9483 | 1 | Total | 32 |
| | | 9942 | 1 | | |
| | | Sub Total | 15 | | |

6 A construction plan for the 1994 workzone along I-55 in Sangamon County was examined; it showed construction occurring approximately between milepost 83 and 92. Of the 32 crashes shown in Table 17, only 11 (34%) had milepost locations within that zone. Actual inspection of the reports may have provided additional details that would have improved the location coding; however, this assumes that the diagram was completed and distance from known reference points clearly shown on the crash report diagram itself. Examination of crash reports specifically prepared for this project showed that police rarely prepared diagrams with measurements.

The issues of under-reporting and inadequate locations suggested that attempts to overlay the crash reports on construction plans would have yielded limited information especially in regard to how crashes related to the layout (traffic control plan) and traffic control devices. Instead, the project used the reports specially provided by the police for 1998 and 1999 for segments that also had onsite visits. The analysis of these reports appears in Chapter 7.

**IMPORTANT FINDINGS**

1. Based on IDOT data, fewer crashes occur at the location of a workzone during construction than when the workzone is not in place.
2. Based on abstracted crash records, compared to non-workzone crashes, those coded as workzone in Illinois are (1) more likely to be injury producing, (2) involved 3 or more vehicles, and (3) be the result of rear-end collisions.
3. In comparison to states reported in the literature, Illinois has more rear-end collisions, substantially more angle collisions, and fewer crashes involving sideswipes and fixed objects.
4. Most frequently one driver strikes another vehicle; collisions with objects account for only 6% of the crashes.
5. "Too fast for conditions" is the contributing factor substantially more often in Illinois than in other states reported in the literature.

## 4. Issues Arising from an Analysis of Workzone Crash Data

### Overview of Quality Issues Affecting Crash Reporting

Availability of the entire Illinois crash database not only provided an opportunity to compare workzone crashes with all crashes for the state as a whole, but also allowed examination of the quality of workzone crashes reporting. At the heart of the analysis, are two of the six dimensions of quality: coverage and accuracy. This discussion is based on earlier work by O'Day (1993) and later analysis of selected state crash reporting by Pfefer, Lucke, and Raub (1993). What both studies highlighted was that the source for most safety data, the police crash report, too often fails to produce comprehensive or accurate data. As a result, the database may not be as usable a tool for drawing inferences as was intended by those who developed it.

Specifically for this analysis, "coverage" refers to collecting data on all crashes which occur within workzones and which are "reportable" under state statutes. Hauer and Hakkert (1988) suggested that as many as 75% of all property-damage-only (PDO) crashes and 50% of non-hospitalization injuries may go unreported. Even when the police arrive at a crash, a report may still not be completed or entered in the state database because damages are below the state threshold. While important to recognize, this factor is not readily a correctable one. The single-most important effect of this lack of including all property-damage-only crashes is that crashes appear to be more severe in terms of injuries than the actual percentage of such crashes.

First, a workzone crash is coded in the "road surface deficiency" (RDEF) element. The Illinois Police Crash Report (PCR) does not require coding this element when the crash does not result in an injury or towing a vehicle. Given that approximately 70% of all crashes are PDO (and a large portion never require a tow), could lead to reported data significantly undercounting the actual events. In other words, even if the officer knew and understood the definition of a workzone, there would be no reason to code the element when the vehicle did not require a tow and no injuries occurred.

The second cause of under-reporting relates to "accuracy." The term means that the element on the report is coded correctly. For example, if a crash occurs at a construction workzone, the "road surface deficiency" element should be coded a 2 for "construction zone." If it is not coded as such, then the crash will not be recorded as a construction zone crash in the database.

From the more than 900,000 crash records from the IDOT database for 1994 and 1995 used for the analysis, 59% of the records had the element "road surface deficiency" coded "1" or "normal." In other words, according to the reporting officer, a workzone was not present. However, as the following discussion suggests, the officer was likely to miscode this field even when a workzone was present. A code of 0 or 99 which would have appeared if the element was left uncoded, was present in 39% of the records. Together, these three codes covered 98% of all crashes reported in the two years (a code of 2 for "construction zone" appeared on only 1.5% of the reports recorded).

In addition to reasons why crashes which did occur in the workzone are not counted, there is an additional problem in that police officers may not be sure when to consider the location a workzone. Two situations affect the coding. First, the reporting officer may not consider the crash to have occurred in the zone even though one is nearby because the officer has assumed (or been trained) that only the working area constitutes a zone. Second, the officer may assume that a workzone exists only when work is in progress. Both issues arise from a lack of adequate training of the officers, and supervisory failure to review and correct crash reports.

The remainder of this chapter addresses what has been discovered by examining crash data from the years 1994 through 1995, using all data maintained on the State of Illinois crash database.[7] It is intended to show that workzone crashes may be occurring more frequently than reported. Commentary here reflects on the original source of the data, the PCR. While the Illinois Department of Transportation (IDOT) strives to ensure high quality in their data entry, built-in limitations of police reporting along with the reduction of attention paid to crash reporting by the police (Pfefer, Lucke, and Raub 1993) as a result of limited manpower and budgets, will reduce the quality of the data received.

### Workzone and Non-Workzone Crashes for 1994 and 1995

**Table 19**
**1994 and 1995 Crash Reports Submitted to IDOT**

| | 1994 | 1995 |
|---|---|---|
| Coded Workzone | 7,749 | 6,206 |
| All Other | 445,146 | 455,818 |
| Total | 452,895 | 462,024 |
| % Coded Workzone | 1.7% | 1.3% |

Based on crash data, as shown in Table 19, 7,749 (1.7%) of the 452,895 crashes reported in 1994 and 6,206 (1.3%) of 462,024 crashes in 1995 occurred in workzones. It is these frequencies of crashes and their percentage of all crashes which has served as a basis for reporting on workzone crashes in Illinois. However, as further discussion will show, the values reported in Table 19 may be under-reported by a magnitude of three to four which means that workzone crashes in 1994 and 1995 could have represented as many as 5 to 7 percent instead of less than 2 percent of the crashes recorded statewide. This section briefly examines the relationship between crashes recorded as occurring and not occurring in work-zones for each of the two years.

In this section, a few elements about the crashes were chosen to compare workzone with non-workzone crashes. The analysis here is used later to identify differences that occur when the undercounting of workzone crashes is adjusted. Table 20 presents five elements: day of the week, severity, hour grouping (in 3-hour blocks), number of vehicles involved, and type of collision.

---

[7] 1996 data were available, but only crashes occurring on state maintained routes or those involving a fatality were recorded. This change in processing data generated a significant decrease in reported crashes, especially in the urban areas which generally have the most workzone crashes.

## Table 20
## Comparing Selected Elements from Illinois Crash Data Showing Percent of Total

| | 1994 | | 1995 | |
|---|---|---|---|---|
| **Day of Week** | **Workzone** | **Non-Workzone** | **Workzone** | **Non-Workzone** |
| SUN | 9.9% | 10.5% | 9.9% | 10.8% |
| MON | 14.9% | 14.2% | 14.1% | 13.9% |
| TUE | 14.9% | 14.4% | 14.8% | 14.4% |
| WED | 14.0% | 14.2% | 15.1% | 14.2% |
| THU | 15.6% | 15.0% | 16.0% | 14.5% |
| FRI | 17.5% | 16.8% | 17.4% | 17.5% |
| SAT | 13.3% | 14.9% | 12.7% | 14.6% |
| **Degree of Severity** | | | | |
| Fatal | 0.3% | 0.3% | 0.4% | 0.3% |
| Injury | 33.2% | 21.8% | 31.9% | 21.4% |
| PDO | 66.4% | 77.8% | 67.6% | 78.3% |
| **Hour Group** | | | | |
| 01-03 | 5.2% | 4.2% | 5.2% | 4.3% |
| 04-06 | 5.9% | 4.7% | 4.6% | 4.6% |
| 07-09 | 15.3% | 13.7% | 15.2% | 13.5% |
| 10-12 | 15.6% | 14.5% | 16.2% | 14.6% |
| 13-15 | 19.0% | 19.4% | 19.7% | 20.1% |
| 16-18 | 19.4% | 21.8% | 19.4% | 21.6% |
| 19-21 | 10.4% | 11.6% | 10.1% | 11.7% |
| 22-24 | 9.2% | 10.1% | 9.6% | 9.5% |
| **Number of Vehicles** | | | | |
| One | 19.2% | 17.5% | 19.9% | 18.3% |
| Two | 68.6% | 75.5% | 68.7% | 74.6% |
| 3 or More | 12.2% | 7.1% | 11.4% | 7.2% |
| **Collision Type** | | | | |
| Ped./Bike | 1.2% | 1.2% | 1.6% | 2.0% |
| Object | 11.8% | 15.7% | 17.2% | 22.5% |
| Non-Collision | 8.2% | 5.2% | 4.6% | 3.3% |
| Rear-end | 31.3% | 17.8% | 34.9% | 26.0% |
| Head-on | 0.9% | 0.7% | 1.2% | 1.1% |
| Sideswipe Same | 7.8% | 4.7% | 10.2% | 8.5% |
| Sideswipe Opp. | 1.2% | 0.9% | 1.5% | 1.3% |
| Angle/Turn | 17.9% | 20.8% | 23.6% | 31.0% |
| All Other | 20.0% | 32.9% | 5.2% | 4.5% |
| Total | 100.0% | 100.0% | 100.0% | 100.0% |
| Number Crashes | 7,749 | 445,146 | 6,206 | 455,818 |

Comparing the columns for workzone crashes for each of the two years shows few differences. For example, collisions in workzones on Monday's represented 14.9% of all workzones and 14.2% of all other crashes in 1994. In 1995, the percentages were 14.1% and 13.9% respectively. Injury crashes represented 33.2% of workzone crashes in 1994 and 31.9% in 1995. For injury crashes outside the workzone, the percentages were 21.8 and 21.45 respectively. Drawing a comparison by "manner of collision" is more difficult because in 1994, 19% of the workzone crashes and 34% of those coded as not in a workzone fell into the manner of collision category as "all other."

For several elements there are some significant differences between what occurred in a crash reported as "workzone" and one that was not. Most notably, workzone crashes appear more likely to result in an injury than those outside the zone. This finding also has been noted by other authors. In 1994 for example, 33.2% of workzone crashes were injury producing, compared to 21.8% for all crashes at other locations. Another area of substantial differences occurred in the element, "number of vehicles." Crashes in workzones were more likely to involve three or more vehicles and less likely to involve only two. Finally, collisions between two vehicles in workzone were more likely to be classified "rear-end" or "sideswipe, same direction."

## Under-Reporting of Workzone Crashes

### Discrepancies in Reporting Noted

The review of individual records from the IDOT database which had been done to help identify segments to be used in comparing crashes when a workzone was and was not present showed that crashes not coded as workzone were occurring along side (often on the same day and time) as those coded workzone. Table 16, page 33, demonstrated how "workzone" crashes could be coded along side "non-workzone" crashes. In other words, a police report of a crash would show a "workzone" crash at milepost 12.25 on May 12 at 0913. On May 13, a PCR would show a crash not coded as workzone occurring at the same milepost; another report, however, would show a "workzone" crash at milepost 12.09 on the same date. There was a significant likelihood that all three crashes occurred within a workzone. This presumption was supported when reviewing the copies of the 103 reports with the supplemental forms provided specifically for the project. All of these specially prepared reports were for crashes that occurred within a workzone; yet, 45% of these reports did not carry the "workzone" code. Further support also derived from examining workzone plans which showed the workzone to encompass crashes coded both non-workzone during periods when crashes in the same locations were coded workzone.

Appendix B contains the listing for 61 crashes along IL 171 in Cook County as an example. Crashes coded as "workzone" were reported as having occurred in a workzone from milepost 15.78 through 17.49 from mid-April through November. In addition to 22 crashes coded as workzone, 39 carried other roadway deficiency codes even though they occurred on the same segment during the same period. Unless construction plans and contracts for construction are examined for each segment, there is no method which clearly will identify construction zones for all of the sites selected for this analysis. Regardless, by using the criteria specified above, i.e., limiting mileposts and months, presents a conservative picture. All possible reports for that segment, whether coded as workzone or not were included.[8]

## Possible Reasons for Discrepancies

One argument which can be raised is that certain crashes were not recorded as workzone because the construction was in one direction only. However, the records from the driver file for the state crash database also were obtained and examined. These records provide direction of travel. For each segment, the data show that drivers involved in workzone crashes were proceeding in both directions of travel.[9] This finding suggests that the entire roadway was under construction within those segments.

Two other reasons already have been indicated explaining why crashes are not coded. First, and the most likely reason is that for crashes with no injury or towed vehicle, the reporting officer is not required to code the road surface deficiency element. This eliminates knowing that the location was a construction zone. Secondly, the police officer may simply fail to include the correct code (8% of the 1998 and 1999 reports were miscoded). Based on the examination of crash reports done by Pfefer, Lucke, and Raub (1993), this lack of accuracy occurs frequently for many of the reporting elements. In both of these cases, the fault lies not with the database or those that maintain it, but rather with how data are reported and the responsibility for that reporting.

Given this potential under-reporting, the earlier comparison of crashes (Table 16) occurring during and after construction performed earlier may not be valid. It suggested that workzones in Illinois were *safer* than when construction is not present. This finding, of course, also would have directly contradicted the large body of literature on the subject of workzone crashes as well as "common wisdom."

## Revising the Count of Workzone Crashes

To provide a more adequate analysis of workzone crashes, an assumption was made that any crash occurring within the given mileposts and dates did happen within the construction zone. This assumption could overstate crashes. In this case, crashes that truly lie outside the workzone were assumed to lie inside the zone. However, where workzone plans were available, and the milepost was available on the crash report, it was found that crashes coded as "non-workzone" did lie within the mileposts delimiting the workzone. Therefore, an overstatement was assumed to be minimal.

Table 21 contains a summary of the data obtained from the 39 routes. The table is somewhat weighted toward Cook County and Chicago, but these locations also contribute heavily to crashes statewide. In the table, a total of 1,457 crashes were coded as "workzone" representing 19% of the 7,749 crashes so coded in 1994. However, an additional 3,344 crashes also occurred

---

[8] Review of construction plans for District 1, as used for Chapter 6, showed that the segments selected by the assumptions to get those plans fell within the actual construction segments.

[9] In some instances, especially along limited access roadways where there were no intersecting roadways, police reports showed drivers proceeding in all four cardinal positions of the compass.

**Table 21**
**Changes in Crashes on Selected Segments**
**Coded Workzone and Non-Workzone (1994)**

| County | Route Number | Mileposts[1] From | Mileposts[1] To | Months[1] From | Months[1] To | Crashes 1994 Coded Workzone?[2] No | Yes | All | Percent Yes |
|---|---|---|---|---|---|---|---|---|---|
| Boone | IL 76 | 3.77 | 16.53 | 6 | 11 | 5 | 14 | 19 | 73.7% |
| Bureau | I-80 | 38.50 | 54.50 | 7 | 10 | 6 | 10 | 16 | 62.5% |
| Champaign | US 150 | 11.56 | 12.25 | 5 | 12 | 9 | 14 | 23 | 60.9% |
| Cook | US 6 | 8.16 | 10.51 | 6 | 11 | 93 | 27 | 120 | 22.5% |
| | US 12 | 9.24 | 11.31 | 4 | 10 | 114 | 62 | 176 | 35.2% |
| | | 26.56 | 28.96 | 4 | 11 | | | | |
| | IL 43 | 4.61 | 11.55 | 4 | 11 | 250 | 69 | 319 | 21.6% |
| | US 45 | 40.40 | 42.89 | 4 | 11 | 46 | 39 | 85 | 45.9% |
| | I-55 | 76.92 | 79.24 | 4 | 10 | 324 | 69 | 393 | 17.6% |
| | | 82.00 | 93.72 | 4 | 11 | | | | |
| | IL 58 | 8.57 | 27.67 | 6 | 8 | 344 | 34 | 378 | 9.0% |
| | IL 59 | 0.01 | 1.66 | 2 | 11 | 42 | 48 | 90 | 53.3% |
| | IL 62 | 4.97 | 17.06 | 7 | 10 | 128 | 27 | 155 | 17.4% |
| | IL 72 | 5.76 | 9.70 | 4 | 10 | 262 | 41 | 303 | 13.5% |
| | | 13.58 | 15.43 | 4 | 10 | | | | |
| | IL 83 | 53.16 | 54.90 | 8 | 10 | 30 | 15 | 45 | 33.3% |
| | | 65.57 | 67.40 | 8 | 10 | | | | |
| | I-94 | 42.66 | 45.90 | 3 | 10 | 62 | 16 | 78 | 20.5% |
| | IL 131 | 2.45 | 7.23 | 5 | 10 | 168 | 4 | 172 | 2.3% |
| | IL 171 | 15.78 | 17.49 | 4 | 11 | 39 | 22 | 61 | 36.1% |
| | IL 176 | 11.13 | 12.19 | 4 | 8 | 24 | 15 | 39 | 38.5% |
| DuPage | IL 19 | 8.35 | 9.12 | 4 | 6 | 43 | 7 | 50 | 14.0% |
| | US 34 | 3.57 | 4.93 | 7 | 11 | 49 | 28 | 77 | 36.4% |
| | | 15.10 | 16.83 | 6 | 9 | | | | |
| | IL 59 | 13.62 | 16.42 | 4 | 10 | 36 | 50 | 86 | 58.1% |
| | IL 64 | 6.44 | 11.00 | 4 | 11 | 66 | 218 | 284 | 76.8% |
| | IL 83 | 12.07 | 17.97 | 4 | 11 | 152 | 18 | 170 | 10.6% |
| Franklin | I-57 | 62.44 | 80.00 | 4 | 10 | 40 | 28 | 68 | 41.2% |
| Jackson | IL 13 | 21.99 | 23.63 | 4 | 10 | 55 | 12 | 67 | 17.9% |
| Jefferson | I-57 | 80.70 | 96.47 | 5 | 11 | 43 | 24 | 67 | 35.8% |
| Kane | US 34 | 1.97 | 3.82 | 4 | 11 | 38 | 32 | 70 | 45.7% |
| | IL 72 | 18.21 | 19.19 | 2 | 8 | 0 | 18 | 18 | 100.0% |
| Kankakee | I-57 | 12.00 | 12.90 | 5 | 10 | 29 | 39 | 68 | 57.4% |
| | | 19.06 | 23.00 | 3 | 10 | | | | |
| Lake | IL 22 | 10.63 | 12.28 | 3 | 12 | 24 | 29 | 53 | 54.7% |
| | IL 53 | 2.58 | 3.10 | 3 | 12 | 7 | 28 | 35 | 80.0% |
| | IL 83 | 2.42 | 6.47 | 3 | 11 | 11 | 104 | 115 | 90.4% |
| Peoria | I-74 | 82.02 | 89.24 | 5 | 11 | 16 | 14 | 30 | 46.7% |
| St. Clair | I-55 | 0.01 | 2.88 | 2 | 9 | 128 | 54 | 182 | 29.7% |
| Sangamon | I-55 | 0.78 | 2.75 | 7 | 9 | 52 | 18 | 70 | 25.7% |
| | | 6.24 | 9.95 | 6 | 9 | | | | |
| | IL 97 | 7.27 | 8.09 | 4 | 9 | 18 | 14 | 32 | 43.8% |
| Will | I-55 | 40.54 | 52.94 | 4 | 10 | 207 | 56 | 263 | 21.3% |
| | | 57.21 | 69.01 | 4 | 10 | | | | |
| | I-80 | 40.07 | 48.36 | 8 | 11 | 36 | 17 | 53 | 32.1% |
| | IL 171 | 1.67 | 8.80 | 5 | 11 | 33 | 33 | 66 | 50.0% |
| Chicago | I-55 | 86.18 | 96.94 | 5 | 10 | 315 | 90 | 405 | 22.2% |
| All Segments | | Total | | | | 3344 | 1457 | 4801 | 30.3% |
| | | Average of Percentages | | | | | | | 39.9% |
| | | Standard Deviation of Percentages | | | | | | | 23.4% |

Notes:

[1]Mileposts represent segment from first crash identified as workzone (RDEF) to last one

[2]Crashes with the roadway deficiency code (RDEF =2, 3, 4, or 5) are coded "YES" for workzone

on the same routes within the already specified mileposts and dates. In other words, those crashes coded as "workzone" may have represented only 30% of all crashes that should have been so identified; for every crash properly coded, two went uncoded. In the column "Percent Yes" (coded as workzone), there is a large variation from a low of 2% on IL 131 in Cook County to a high of 100% for the 18 crashes reported along IL 72 in Kane County. No clear pattern in the discrepancies appears. Although most of the lower percentages occur where there are larger numbers of crashes, such as in Cook County, only 18% of crashes occurring along IL 13 in Jackson County (rural downstate) were reported as in the workzone. The same type of variation appears by roadway class. Crashes reported as occurring in construction along Interstate roadways ranged from 18% to 63% of the total, and the same variation appeared for other road classifications.

Using the average (1,457 of 4,801 crashes) of 30% coded correctly as workzone as appropriate for under-reporting, there would have been 25,830 workzone crashes in 1994 (instead of 7,749). In 1995, the number would have been 22,010 instead of 6,602. These numbers may overstate the case because of a few roads with very high frequencies of crashes and low percentages reported as construction zone, e.g., IL 72 in Cook County or I-55 in the City of Chicago. If a more conservative approach is taken, using the average of percentages shown in the last column of Table 21, then what is contained on the IDOT database represents 40% of what really occurred. This would mean that 19,370 crashes occurred in 1994 and 16,510 in 1995. Somewhere between the values of 19,730 and 25,830 crashes in 1994, and 16,510 and 22,010 crashes in 1995 probably lies the actual number of workzone crashes for each year. These resulting values therefore mean that workzone crashes may have represented between 4% and 6% of all crashes rather than approximately 1.5% as recorded for 1994 and 1995 combined.

**Using Adjusted Values to Assess Differences**

Given the differences found, an assumption was made that *all* crashes regardless of road surface deficiency coding occurring within the mileposts and dates noted were related to the workzone. All remaining crashes occurring in the same counties, but not within the selected segments and not coded as "construction zone" were assumed to have occurred outside the workzone. Table 22 shows the comparisons between workzone and non-workzone crashes. Of interest to the analysis is that from the 39 routes (47 segments) in 15 counties and Chicago, the revised number of workzone crashes was higher than all crashes coded as such statewide during 1994. On the other hand, the 185,770 crashes assumed to have occurred outside the workzone in the selected counties[10] represented 42% of the statewide crashes. As a result, crashes in workzones for the sample represent 5.0% of all crashes as opposed to 1.7% of the total when using only those coded "construction zone."

Table 22 shows both the frequency and percentages for statewide data for workzones and non-workzones, and for the presumed workzone and non-workzone crashes from the sample segments. The following analysis examines differences between the two sets of percentages.

---

[10] For Chicago, only crashes occurring along the expressways (Interstate System) were used because the selected route for Chicago was I-55 which was not representative of the City as a whole.

**Table 22**

**Comparing Elements Relating to Illinois Crashes Recorded as Workzone or Presumed to Be Workzone**

**Day of the Week**

| | 1994 Frequencies | | | |
|---|---|---|---|---|
| | Statewide Data Coded Workzone? | | Selected Counties Presumed Workzone | |
| Day of Week | Yes | No | Yes | No |
| SUN | 766 | 46,862 | 450 | 17,879 |
| MON | 1,152 | 63,287 | 698 | 26,205 |
| TUE | 1,151 | 63,988 | 668 | 27,462 |
| WED | 1,087 | 63,209 | 732 | 27,430 |
| THU | 1,207 | 66,624 | 739 | 28,753 |
| FRI | 1,358 | 74,750 | 817 | 31,933 |
| SAT | 1,028 | 66,426 | 697 | 26,108 |
| Total | 7,749 | 445,146 | 4,801 | 185,770 |

| | 1994 Percentages | | | |
|---|---|---|---|---|
| | Statewide Data Coded Workzone? | | Selected Counties Presumed Workzone | |
| Day of Week | Yes | No | Yes | No |
| SUN | 9.9% | 10.5% | 9.4% | 9.6% |
| MON | 14.9% | 14.2% | 14.5% | 14.1% |
| TUE | 14.9% | 14.4% | 13.9% | 14.8% |
| WED | 14.0% | 14.2% | 15.2% | 14.8% |
| THU | 15.6% | 15.0% | 15.4% | 15.5% |
| FRI | 17.5% | 16.8% | 17.0% | 17.2% |
| SAT | 13.3% | 14.9% | 14.5% | 14.1% |
| Total | 100.0% | 100.0% | 100.0% | 100.0% |

**Severity**

| | 1994 Frequencies | | | |
|---|---|---|---|---|
| | Statewide Data Coded Workzone? | | Selected Counties Presumed Workzone | |
| Degree of Severity | Yes | No | Yes | No |
| Fatal | 26 | 1,395 | 25 | 593 |
| Injury | 2,575 | 97,233 | 1,364 | 48,283 |
| PDO | 5,148 | 346,544 | 3,412 | 136,894 |
| Total | 7,749 | 445,172 | 4,801 | 185,770 |

| | 1994 Percentages | | | |
|---|---|---|---|---|
| | Statewide Data Coded Workzone? | | Selected Counties Presumed Workzone | |
| Degree of Severity | Yes | No | Yes | No |
| Fatal | 0.3% | 0.3% | 0.5% | 0.3% |
| Injury | 33.2% | 21.8% | 28.4% | 26.0% |
| PDO | 66.4% | 77.8% | 71.1% | 73.7% |
| Total | 100.0% | 100.0% | 100.0% | 100.0% |

**Number of Vehicles**

| | 1994 Frequencies | | | |
|---|---|---|---|---|
| | Statewide Data Coded Workzone? | | Selected Counties Presumed Workzone | |
| Number Vehicles | Yes | No | Yes | No |
| One | 1,490 | 77,762 | 675 | 30,988 |
| Two | 5,315 | 335,950 | 3,404 | 138,937 |
| 3 or More | 944 | 31,434 | 722 | 15,845 |
| Total | 7,749 | 445,146 | 4,801 | 185,770 |

| | 1994 Percentages | | | |
|---|---|---|---|---|
| | Statewide Data Coded Workzone? | | Selected Counties Presumed Workzone | |
| Number Vehicles | Yes | No | Yes | No |
| One | 19.2% | 17.5% | 14.1% | 16.7% |
| Two | 68.6% | 75.5% | 70.9% | 74.8% |
| 3 or More | 12.2% | 7.1% | 15.0% | 8.5% |
| Total | 100.0% | 100.0% | 100.0% | 100.0% |

## Table 22 (continued)
## Comparing Elements Relating to Illinois Crashes Recorded as Workzone or Presumed to Be Workzone

### Manner of Collision

| Collision | 1994 Frequencies | | | |
|---|---|---|---|---|
| | Statewide Data Coded Workzone? | | Selected Counties Presumed Workzone | |
| Type | Yes | No | Yes | No |
| Overturn | 73 | 3,751 | 46 | 1,443 |
| Ped./Bike | 91 | 5,306 | 40 | 3,439 |
| Object | 913 | 69,998 | 514 | 35,323 |
| Non-Collision | 634 | 22,115 | 306 | 12,127 |
| Rear-end | 2,423 | 79,216 | 2,141 | 55,491 |
| Head-on | 66 | 3,139 | 36 | 1,944 |
| Sideswipe Same | 601 | 718 | 599 | 14,556 |
| Sideswipe Opp. | 90 | 3,761 | 47 | 2,247 |
| Angle/Turn | 1,385 | 92,536 | 1,059 | 58,805 |
| All Other | 1,473 | 144,604 | 13 | 395 |
| Total | 7,749 | 425,144 | 4,801 | 185,770 |

| Collision | 1994 Percentages | | | |
|---|---|---|---|---|
| | Statewide Data Coded Workzone? | | Selected Counties Presumed Workzone | |
| Type | Yes | No | Yes | No |
| Overturn | 0.9% | 0.9% | 1.0% | 0.8% |
| Ped./Bike | 1.2% | 1.2% | 0.8% | 1.9% |
| Object | 11.8% | 16.5% | 10.7% | 19.0% |
| Non-Collision | 8.2% | 5.2% | 6.4% | 6.5% |
| Rear-end | 31.3% | 18.6% | 44.6% | 29.9% |
| Head-on | 0.9% | 0.7% | 0.7% | 1.0% |
| Sideswipe Same | 7.8% | 0.2% | 12.5% | 7.8% |
| Sideswipe Opp. | 1.2% | 0.9% | 1.0% | 1.2% |
| Angle/Turn | 17.9% | 21.8% | 22.1% | 31.7% |
| All Other | 19.0% | 34.0% | 0.3% | 0.2% |
| Total | 100.0% | 100.0% | 100.0% | 100.0% |

### Time of Day

| Hour | 1994 Frequencies | | | |
|---|---|---|---|---|
| | Statewide Data Coded Workzone? | | Selected Counties Presumed Workzone | |
| Group | Yes | No | Yes | No |
| 0001-0300 | 401 | 18,634 | 228 | 10,491 |
| 0301-0600 | 459 | 20,833 | 163 | 5,191 |
| 0601-0900 | 1,188 | 60,824 | 711 | 25,410 |
| 0901-1200 | 1,206 | 64,693 | 640 | 23,131 |
| 1201-1500 | 1,471 | 86,480 | 865 | 33,462 |
| 1501-1800 | 1,503 | 96,981 | 1,181 | 46,226 |
| 1801-2100 | 805 | 51,788 | 650 | 26,412 |
| 2101-2400 | 716 | 44,913 | 363 | 15,447 |
| Total | 7,749 | 445,146 | 4,801 | 185,770 |

| Hour | 1994 Percentages | | | |
|---|---|---|---|---|
| | Statewide Data Coded Workzone? | | Selected Counties Presumed Workzone | |
| Group | Yes | No | Yes | No |
| 0001-0300 | 5.2% | 4.2% | 4.7% | 5.6% |
| 0301-0600 | 5.9% | 4.7% | 3.4% | 2.8% |
| 0601-0900 | 15.3% | 13.7% | 14.8% | 13.7% |
| 0901-1200 | 15.6% | 14.5% | 13.3% | 12.5% |
| 1201-1500 | 19.0% | 19.4% | 18.0% | 18.0% |
| 1501-1800 | 19.4% | 21.8% | 24.6% | 24.9% |
| 1801-2100 | 10.4% | 11.6% | 13.5% | 14.2% |
| 2101-2400 | 9.2% | 10.1% | 7.6% | 8.3% |
| Total | 100.0% | 100.0% | 100.0% | 100.0% |

For day-of-the-week, no substantial differences appeared. Using crashes "presumed" to have occurred in a workzone show fewer differences in percentages from those outside the zone than a similar comparison with the 1994 crashes. On the other hand, crash severity showed substantial differences. The originally coded workzone crashes showed that injury producing crashes were significantly over-represented and PDO under-represented. As discussed earlier, other researchers have presented similar findings. For the sample segments where all crashes are presumed to be in the workzone, the differences all but disappeared. Injury producing crashes represented 28% of all crashes occurring in workzones compared to 26% occurring outside.

Differences between the originally coded and revised workzone crash coding also appeared when examining number of vehicles. The expanded base also showed even more over-representation for three or more vehicles, but it also showed the single-vehicle crashes were significantly under-represented. The 1994 data had suggested that single-vehicle crashes also were over-represented.

Collisions with objects were under-represented, and "rear-end" and "sideswipe, same direction," were over-represented in the original reporting. With the revised database, the degree of under- or over-representation became more pronounced. Rear-end collisions now made up 45% of the crashes as opposed to 31% previously. Other manners of collisions remained similar regardless of the data source.

Finally, the 1994 original workzone-coded crashes showed minimal hourly differences from all other crashes. From 1501 through 1800 hours, they were slightly under-represented. When using the expanded workzone coding, the differences disappeared.

## Comparing Crashes from Year-to-Year

Crashes occurring during construction are expected to be higher than before or after the work because of the greater number of hazards presented to motorists and more congested conditions. Most of the literature has shown that crashes along a segment of roadway will increase during the construction compared both to the prior and following years. In examining changes in crashes, it is preferable to use both before and after. Using just the after period could be misleading if the construction was designed to correct hazardous situations. However, because of how data were received and analyzed, the comparison was drawn with crashes occurring during construction in 1994 and after it was completed in 1995 (in each case, none of the crashes in the following year are coded as "workzone.".

Table 23 displays crashes occurring on the same segments in 1995 when construction zones did not exist (note, that for 1995, US 45 in Cook County and IL 64 in DuPage County all had substantial numbers of crashes coded as construction zone, and these locations were not included in the comparison). All crashes whether coded workzone or not for 1994 are compared to the crashes for the same segments and months in 1995.[11]

---

[11] These segments did not have crashes coded as workzone in 1995, and except for IL 131in Cook County, segments with workzone always had some of the crashes coded as such.

**Table 23**
**Changes in Crashes on Selected Segments**
**From 1994 (Workzone) to 1995 (Non-Workzone)**

| | | Crashes | | | | |
|---|---|---|---|---|---|---|
| | | 1994 | | | | Percent |
| | Route | Coded Workzone? [1] | | | 1995 | Change |
| County | Lanes | No | Yes | All | No Zone | 94-95 |
| Boone | IL 76 | 5 | 14 | 19 | 29 | 52.6% |
| Bureau | I-80 | 6 | 10 | 16 | 20 | 25.0% |
| Champaign | US 150 | 9 | 14 | 23 | 13 | -43.5% |
| Cook | US 6 | 93 | 27 | 120 | 125 | 4.2% |
| | US 12 | 114 | 62 | 176 | 233 | 32.4% |
| | IL 43 | 250 | 69 | 319 | 261 | -18.2% |
| | US 45 | 46 | 39 | 85 | WZ[2] | |
| | I-55 | 324 | 69 | 393 | 393 | 0.0% |
| | IL 58 | 344 | 34 | 378 | 342 | -9.5% |
| | IL 59 | 42 | 48 | 90 | 47 | -47.8% |
| | IL 62 | 128 | 27 | 155 | 115 | -25.8% |
| | IL 72 | 262 | 41 | 303 | 249 | -17.8% |
| | IL 83 | 30 | 15 | 45 | 48 | 6.7% |
| | I-94 | 62 | 16 | 78 | 52 | -33.3% |
| | IL 131 | 168 | 4 | 172 | 207 | 20.3% |
| | IL 171 | 39 | 22 | 61 | 31 | -49.2% |
| | IL 176 | 24 | 15 | 39 | 30 | -23.1% |
| DuPage | IL 19 | 43 | 7 | 50 | 88 | 76.0% |
| | US 34 | 49 | 28 | 77 | 36 | -53.2% |
| | IL 59 | 36 | 50 | 86 | 68 | -20.9% |
| | IL 64 | 66 | 218 | 284 | WZ[2] | |
| | IL 83 | 152 | 18 | 170 | 162 | -4.7% |
| Franklin | I-57 | 40 | 28 | 68 | 55 | -19.1% |
| Jackson | IL 13 | 55 | 12 | 67 | 47 | -29.9% |
| Jefferson | I-57 | 43 | 24 | 67 | 64 | -4.5% |
| Kane | US 34 | 38 | 32 | 70 | NS[3] | |
| | IL 72 | 0 | 18 | 18 | 2 | -88.9% |
| Kankakee | I-57 | 29 | 39 | 68 | 18 | -73.5% |
| Lake | IL 22 | 24 | 29 | 53 | 40 | -24.5% |
| | IL 53 | 7 | 28 | 35 | 18 | -48.6% |
| | IL 83 | 11 | 104 | 115 | 74 | -35.7% |
| Peoria | I-74 | 16 | 14 | 30 | 16 | -46.7% |
| St. Clair | I-55 | 128 | 54 | 182 | 206 | 13.2% |
| Sangamon | I-55 | 52 | 18 | 70 | 52 | -25.7% |
| | IL 97 | 18 | 14 | 32 | 25 | -21.9% |
| Will | I-55 | 207 | 56 | 263 | WZ[2] | |
| | I-80 | 36 | 17 | 53 | 56 | 5.7% |
| | IL 171 | 33 | 33 | 66 | 36 | -45.5% |
| Chicago | I-55 | 315 | 90 | 405 | 530 | 30.9% |
| All Segments | Total | 3344 | 1457 | 4801 | 3788 | -21.1% |
| | Average | | | | | -15.6% |
| | s.d. | | | | | 34.5% |

Notes:

[1]Mileposts represent segment from first crash identified as workzone (RDEF) to last one

[2]Presumed to be a workzone in 1995.

[3]No crashes recorded for this segment in 1995.

Using all crashes occurring in the zones during 1994 as the base, the frequency of crashes in 1995 fell by 21% (using an average of percentages showed a 16% decrease). The largest decrease was 89% along IL 72 in Kane County, followed by a 77% decrease along I-57 in Kankakee and a 53% decrease along US 34 in DuPage County. On the other hand, crashes along 10 segments had increases. For increases, the largest was 76% on IL 19 in DuPage County (from 50 during construction to 88 after) followed by a 53% increase along IL 76 in Boone County and 32% along US 12 in Cook County.

Overall, there were 10 increases (and one no change) at 36 of the 39 sites (three of the sites were excluded because comparisons were not meaningful or data were absent) and 25 decreases. This result compares to only four decreases found when only those crashes coded as "workzone" were used (see Table 16 in Chapter 3). The 25 decreases appears more aligned with other research findings than the original number of four based on the raw data. Moreover, where increases occurred, the two largest were 70% and 33%.

**Some Concluding Comments**

The analysis presented here is intended to show how coverage and accuracy of the PCR can significantly affect conclusions drawn from crash statistics, especially if they are to be applied to specialized analysis such as contained in the study of workzone safety. It also calls attention to the fact that workzone crashes may be occurring between three and five times as frequently as reported. The conclusion that workzone crashes are substantially under-reported only adds weight to attention being given to controlling crashes at these locations.

Several other findings should be noted. First, workzone crashes may not be as severe as has been suggested from the analysis of crashes coded as "construction zone" on the PCR and entered into the database. This finding also may have colored conclusions drawn by other researchers as expressed in the literature where they have called attention to the significant "dangers" to workers and to the risk of injury and death. Fatalities in workzones, even the adjusted data, occurred at the same percentage as those in all other crashes. An argument which could be forwarded is that because much of the work takes place on controlled access roadways, and they have a lower percentage of injury crashes, that the revised lower percentage was a product of that environment. However, the injury crash percentage in the presumed workzones on both rural and urban interstates also was below the statewide percentages for those roadways.

Second, rear-end collisions are the most frequent crashes by several magnitudes. Angle and turning collisions follow, but are not over-represented. Along with sideswipe, same direction crashes, which are over-represented, these categories can be traced to difficulties facing the driver approaching and within the actual working area. The source of the data, i.e., raw data or revised data, for this conclusion did not change the findings measurably, although the revised data showed an increase in the frequency of rear-end collisions.

Two minor changes to the reporting structure on the police crash report could improve the data significantly. First, whether or not a workzone exists could be moved to a check box similar to that used for towing or fire. Second, the directions for checking the box would be that any crash occurring within the signs marking construction zone (including approach, taper, working zone, and exit) are considered as occurring in a construction zone. Such a designation would be included *regardless of the presence of work or workers.* The current policy of including workzone in a category which does not need to be checked, and which is not a"deficiency" *per se*, does not encourage accurate reporting. This could be observed from the crash records where a "normal" code constitutes the most frequent roadway surface deficiency, even when the crash most likely occurred within the workzone.

**IMPORTANT FINDINGS**

1. Crashes coded as "construction zone" represent between 30% and 40% of crashes occurring within workzones.
2. Adjusting for probable under-reporting suggests that workzone crashes, while occurring more frequently than for similar segments when workzones are not present are no more likely to involve an injury or death than crashes at other times.
3. Except for differences in the manner of collision, few differences appear between other crash-related factors, e.g. time-of-day or day-of-week, comparing crashes in and outside workzones.
4. Changes to the Illinois Police Crash Report coupled with providing a clearly designated workzone and refresher training should generate great accuracy and coverage in reporting workzone crashes.

## 5. Use of Supplemental Reporting for Selected 1998 Zones

### Supplemental Reporting

The supplemental form, shown in Appendix C and in Figure 5, which accompanied the Illinois PCR provided more information about crashes occurring at a select number of construction sites: I-74 Moline County, I-55 Will County, I-90 DuPage County, I-94 Cook/Lake Counties, I-80 Will County, IL 120 Lake County, and IL 68 Cook County in 1998 and 1999 than would have been available from the PCR itself. Police reported 110 crashes at seven sites; however, in their opinion, the workzone played a role only in 103 of them. Nine of the crashes occurred on 4-lane state numbered arterial roadways; the remainder occurred at five Interstate locations.

On the form, the reporting officer was asked to indicate where in the workzone (using a diagram on the back of each report) the crash occurred using four locations: approach, taper, construction area, and exit. Each officer also recorded one or more elements of the environment, and one or more actions by the drivers that contributed to the crash. Finally, the police agency completing the supplemental report also provided a copy of the PCR. Both the crash reports and accompanying forms provided the basis for the analysis reported in this section.

### Description of Crashes

Chapter 3 discussed crashes occurring in 1994 and 1995. This chapter compares some of the findings to the police crash reports with accompanying supplemental reports for 1998 and 1999. It then proceeds to show how revised counts for 1994 and 1995, based on the discussion in the previous chapter, make a difference in the findings. As shown in Table 24, the data from the 1998-99 special reporting showed workzone crashes to be less severe than those reported from the IDOT database for 1994 and 1995. The 22.3% injury producing crashes from the special reporting was closer to the rate found in crashes shown as "non-workzone" from the IDOT database. The percentage also agrees with the revised percentages computed using the assumption that workzone crashes were significantly undercounted.

Some cross tabulations of the 1998/99 specially reported workzone crashes also were performed to describe the crashes in greater detail. As shown in Table 25, approximately 60% of the crashes occurred within the working area; 40% fell in the approach and taper. Of that 40%, 22 percentage points represented the approach and 18 the taper. Those crashes outside the work area were approximately 50% more likely to be injury-producing than those within the zone; however, the chi square test of differences was not significant at the 0.05 level.[12] This injury percentage, even though obtained from a small sample, mirrors the percentage computed when

[12] Although not included as a crash recorded during supplemental reporting because it occurred before the reports were requested, the only fatal crash in all of the selected zones from May through October occurred along I-74 in Moline County at the taper when a truck failed to negotiate the merge and overturned.

## Figure 5
## Supplemental Crash Reporting for Construction Zone Crashes Illinois State Police

(To Be Completed for All Crashes Occurring Within a Construction Zone Reported On-Scene)

Date: ________________ ISP Crash Report Nbr. ______________________

1. Did the construction zone (as defined on the reverse side) contribute to the crash (did it occur because the construction zone was there)?

   ❑ NO **Do not complete the form**

   ❑ *YES* ***Please continue with the form***

2. Based on the picture shown on the reverse side, where did the crash occur (check one)?

   ❑ Advance area
   ❑ Taper or crossover (to two-way traffic)
   ❑ Work area
   ❑ Exit

   Approximately how far from the point marking the *end of the taper (or crossover) and start of the work area* did the crash occur:

   ______ feet BEFORE or AFTER
   (circle one)

3. Which of the following elements related to the construction zone contributed to the crash? (check *all* that apply)

   ❑ Interference with the driving lane from *construction equipment or personnel.*
   ❑ Distraction resulting from activity in the work area.
   ❑ Obstructed view of traffic by vehicles, signs, or activity in the work area.
   ❑ Interference with the driving lane from *traffic control devices (cones, barriers, etc.).*
   ❑ Missing, improperly placed, or ambiguous striping, cones, barriers, or traffic control devices.
   ❑ Damaged pavement or unexpected changes in pavement levels.
   ❑ Narrow lanes
   ❑ Lack of adequate escape
   ❑ Other - please specify:

   ______________________________

4. What actions of motorists or vehicle, including the at-fault driver, contributed to the crash? (check all that apply)

   ❑ Stopping (stopped), sudden slowing, or driving at speed substantially below that of other traffic.
   ❑ Driving outside/straddling the marked lane.
   ❑ Unexpected lane change.
   ❑ Failure to yield from on-ramp or merging at taper.
   ❑ Driving *in excess* of the speed limit (indicate speed limit: ______ mph)
   ❑ Rapid acceleration, high speed, or lane changes in the exit zone.
   ❑ Following too closely.
   ❑ Driving too rapidly or improper passing prior to the taper.
   ❑ Distraction from within vehicle
   ❑ Alcohol, drugs, or asleep
   ❑ Vehicle defect
   ❑ Other, please specify:

   ______________________________

5. Was construction in progress at the time the crash occurred?

   ❑ YES ❑ NO

6. In your opinion, could changes have been made in design, marking, or other aspects of the construction zone that might have helped prevent the collision?

   ❑ YES ❑ NO

Specify: ______________________________________

______________________________________________

**Table 24**
**Severity of Workzone and Non-Workzone Crashes**
**1994 and 1995 Original IDOT Data Compared to Special Reporting**

| Severity | | 1994 Non-Workzone | 1994 Workzone | 1995 Non-Workzone | 1995 Workzone | 1998/9 Special Reporting |
|---|---|---|---|---|---|---|
| Fatal | Frequency | 1,369 | 26 | 1,376 | 26 | 0 |
| | Percent | 0.3% | 0.3% | 0.3% | 0.4% | 0.0% |
| Injury | Frequency | 97,233 | 2,575 | 97,328 | 1,982 | 23 |
| | Percent | 21.8% | 33.2% | 21.4% | 31.9% | 22.3% |
| PDO | Frequency | 346,544 | 5,148 | 357,114 | 4,198 | 80 |
| | Percent | 77.8% | 66.4% | 78.3% | 67.6% | 77.7% |
| Total | | 445,146 | 7,749 | 455,818 | 6,206 | 103 |

the assumption was made that all crashes within the selected segment and dates should be coded as workzone (Chapter 4). The argument that the percentage of injury was low because most of the supplemental data collected were for crashes on Interstate roadways, likewise is countered by the fact that only 22% of workzone crashes resulted in an injury. This percentage is lower than the percentage of injury crashes for urban and rural Interstate roadways (24% and 26% respectively) when workzones are not present.

**Table 25**
**Workzone Crashes by Severity and Manner of Collision**

| 1998/99 Location in Workzone | Severity: Injury | Severity: PDO | Injury as Percent* | All Crashes: Frequency | All Crashes: Percent |
|---|---|---|---|---|---|
| Approach (Advance) | 7 | 16 | 30.4% | 23 | 22.3% |
| Taper | 5 | 13 | 27.8% | 18 | 17.5% |
| Work Area | 11 | 50 | 18.0% | 61 | 59.2% |
| Exit | 0 | 1 | 0.0% | 1 | 1.0% |
| Total | 23 | 80 | 22.3% | 103 | |

| | Manner of Collision (selected): Pedest. | Object | Rear-end | Sideswipe, Same Direction | Other |
|---|---|---|---|---|---|
| Approach (Advance) | 1 | 1 | 15 | 5 | 1 |
| Taper | 0 | 0 | 4 | 13 | 1 |
| Work Area | 0 | 10 | 39 | 8 | 4 |
| Exit | 0 | 1 | 0 | 0 | 0 |
| Total | 1 | 12 | 58 | 26 | 6 |
| Percent of Crashes | 1.0% | 11.7% | 56.3% | 25.2% | 5.8% |
| IDOT Data (Original) | 2.2% | 15.8% | 33.1% | 8.0% | 16.7% |

*Using IDOT data coded workzones from 1994 and 1995 showed 33.5% injuries.

Only one pedestrian was involved, and he was a motorist who had exited his vehicle in the approach area. The Illinois data suggest that one pedestrian in 110 crashes is normal, but other studies suggest that collisions with pedestrians occur more frequently.

The most frequent type of collision overall was a rear-end followed by a sideswipe, both vehicles traveling in the same direction (Table 25). The rear-end collisions happened significantly more frequently than even those reported as workzone crashes in the IDOT database. Collisions with objects closely agreed with the IDOT workzone database, and both were substantially lower than findings from other research. Limitations to the sample, and the fact that it involved only four-lane, suburban or rural roadways without intersections would affect the types of collisions recorded.

Within the working area, the largest percentage of crashes was rear-end. This manner of collision was over-represented in the working area with 39 of 58 (67%) of the crashes represented as opposed to 56% overall. Given the narrower lanes, and "Jersey" type concrete barriers, there was no escape. However, rear-end collisions also occurred approximately as frequently in the approach. Sudden, unexpected slowing of vehicles for the queue formed as a result of merging traffic probably was the most likely contributor.

In the taper, the most frequent crash was sideswipe, same-direction with 13 of 18 (72%) occurring. Improper merging likely would account for most of the crashes recorded.

Contrary to other studies in which pedestrians (presumed to be workers) often have been found to be victims in crashes in the working area, only one crash involved a pedestrian, and this occurred in the approach portion. Because precise location within the workzone is not available from statewide data, this analysis is the first time distinctions can be drawn between the specific sections of the construction zone.

In addition to locating the crashes, reporting officers were asked two questions:

1) Was activity in progress within the construction zone when the crash occurred, and
2) Could changes have been made to the design or traffic control devices that might have helped prevent the crash?

Police also were asked to indicate if work was in progress at the time of the crash. Of the 103 reports, 61 or 59% of the crashes occurred when work was in progress. When no work was in progress, the collision more often occurred outside the working area (22 of 42 crashes) and the manner of collision was about equally likely to be rear-end or sideswipe (16 rear-end and 13 sideswipe). On the other hand, rear-end crashes were significantly higher when work was in progress (42 of 58 rear-end collisions occurred then). Injuries were equally likely to occur whether work was in progress or not.

Officers investigating the crashes and using the supplemental forms checked "changes needed" in 15% of the 103 crashes, but the form failed to ask what changes the officer believed were needed. Although the Resident Engineer (RE) in charge of the project also should be identifying needed changes based on reports of crashes, the investigating officer is aware of conditions present at the time of the crash which might not be known to others. Therefore, the officer's recording of needed changes and providing this with a copy of the PCR to the RE might be useful for identifying potential corrective action. Additionally, most of the time when the officer recommended a change, the crash also occurred within the work area. In the future, when crashes occur within a workzone, the officer should note whether changes might be needed within the narrative and share that finding with the RE.

## Contributing Factors

### Driving Environment

The reporting officer was asked to indicate which elements from a list related to the driving environment may have contributed to the crash. They also were asked to indicate contributing driver actions. In each crash, the officer could check more than one element and action. The average number of elements checked was 1.1; an average of 1.5 driver actions were indicated.

Of the 114 indicated contributing elements, 24% (27) were the lack of escape (Table 26). Interference from traffic control devices (TCD), narrow lanes, and construction activity each accounted for approximately 12%. The category of "other" represented a wide variety of elements. Most frequently indicated was "stopped traffic."

**Table 26**
**Contributing Elements to Crashes (External)**

| Contributing | All | Severity of Crash | | Location | | | |
|---|---|---|---|---|---|---|---|
| Elements* | Crashes | Injury | PDO | Approach | Taper | Workzone | Exit |
| Interference | | | | | | | |
| TCD | 13 | 2 | 11 | 6 | 0 | 7 | 0 |
| Activity | 14 | 3 | 11 | 0 | 2 | 12 | 0 |
| Constr. Equip. | 5 | 2 | 3 | 1 | 1 | 3 | 0 |
| Obstructed View | 7 | 0 | 7 | 0 | 3 | 4 | 0 |
| TCD Problem | 6 | 1 | 5 | 0 | 1 | 4 | 1 |
| Pavement | 6 | 1 | 5 | 0 | 0 | 6 | 0 |
| Narrow Lanes | 14 | 6 | 8 | 1 | 5 | 8 | 0 |
| No Escape | 27 | 6 | 21 | 4 | 6 | 17 | 0 |
| Other | 22 | 7 | 15 | 9 | 4 | 9 | 0 |
| Total | 114 | 28 | 86 | 21 | 22 | 70 | 1 |

* Police could check one or more contributing elements

### Driver Actions

Police checked 152 driver actions that contributed to the crash (Table 27). Stopping or sudden slowing was checked 38 times or 25% of all crashes. The second most frequently checked was "following too closely" with 25 (16%) of the time. Both of these actions should have been indicated given that as many as 68% of the crashes were rear-end which results from the interaction of these two driver actions. Failure to yield and distractions from within the vehicle accounted for 13% and 11% respectively of the driver elements. On the other hand, excessive speed (above the speed limit) was checked only 5 times; three were inside the work area and two outside. Speeding, which represented 3% of all driver actions, was substantially lower than reports from most other researchers except the case studies by Nemeth and Ha (1995). These findings from driver actions may have implications for how enforcement should be performed (more is discussed in Chapter 9 as part of the recommendations).

**Table 27**
**Contributing Driver Actions to Crashes**

| Driver | All | Severity of Crash | | Location | | | |
|---|---|---|---|---|---|---|---|
| Actions | Crashes | Injury | PDO | Approach | Taper | Workzone | Exit |
| Sudden Slow/Stop | 38 | 10 | 28 | 7 | 4 | 27 | 0 |
| Drive Outside Lane | 9 | 1 | 8 | 5 | 2 | 2 | 0 |
| Improp. Lane Change | 13 | 2 | 11 | 3 | 5 | 4 | 1 |
| Failure to Yield | 19 | 2 | 17 | 1 | 11 | 7 | 0 |
| Exceed Speed Limit | 5 | 2 | 3 | 1 | 1 | 3 | 0 |
| Exit Behavior | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| Following Too Close | 25 | 6 | 19 | 6 | 1 | 18 | 0 |
| Improper Approach | 2 | 0 | 2 | 2 | 0 | 0 | 0 |
| Distract Inside Vehicle | 17 | 8 | 9 | 6 | 2 | 9 | 0 |
| Alcohol/Drugs | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| Vehicle Defect | 3 | 1 | 2 | 0 | 1 | 2 | 0 |
| Other | 19 | 2 | 17 | 3 | 0 | 16 | 0 |

What the officers checked as contributing factors and what they cited motorists under Illinois law was in disagreement. Officers cited drivers for traffic violations in 64% of the crashes. On the supplemental form they indicated speeding in only 5% of the crashes. Yet, 73% of the tickets were written for violation of 625 ILCS 11/601(a), "speed too fast to avoid an accident" (too fast for conditions). Because both the Insurance Institute for Highway Safety (IIHS) and the National Highway Traffic Safety Administration consider "speed too fast for conditions" as "speeding," the interpretation would be that speeding was the contributing factor in most of the crashes.

## Drivers

Some data from the special reporting also were recorded describing the at-fault drivers involved in crashes.[13] As shown in Table 28, males were the at-fault driver in 70% of the crashes. Based on the 1994/95 state database (using only those crashes which had been coded as RDEF=2 on the PCR and not adjusting for the under-reported crashes), male drivers were the at-fault driver in 63% of all workzone crashes. The percentages were similar. Drivers ages 65 and older were represented in 10% of the specially reported crashes, a rate more than 50% greater than the 6% representation statewide. On the other hand, those drivers between ages 26 and 64 were

[13] Traditionally, the first driver listed on the police crash report is considered the driver at fault in the crash. This analysis is based on the first listed driver on each of the supplemental reports.

somewhat under-represented in the special reporting, but they accounted for 70% of the injury crashes.

In terms of involvement in crashes by location outside the work area, drivers 65 and older were more likely to be involved in a crash in the taper. Drivers ages 25 and younger were more likely to have a crash in the approach.

Crashes involving 3 or more vehicles occurred approximately 18% of the time. This is 1.5 times the percentage of such crashes in workzones statewide. On the other hand, single-vehicle crashes were less likely to appear in the supplemental crash reports than in the statewide database. Moreover, when crashes involving three or more vehicles occurred they were twice as likely to result in an injury than crashes involving fewer vehicles.

**Additional Analysis Based on the Narrative and Diagram**

A thorough discussion based on the narratives and diagrams from the PCR's submitted to the researchers by the different police agencies appears in Chapter 6 under the specific sites that were visited. This discussion indicates ways in which the narrative and diagrams can be used to supplement analysis of the crash reports. For example, based on crash reports from the first seven crashes along I-74, the RE corrected a potential defect in the traffic control plan.

**Some Conclusions**

The above analysis suggests several promising approaches. Many involve changes to the traffic control plans and layout rather than TCD's as appropriate means of reducing the potential of crashes and injuries. First, the narrow lanes and lack of escape are serious problems. Yet, this configuration is most likely to occur at locations where there is a need to maintain as much capacity as possible. In this sense, the traffic control plan which uses narrow lanes and "Jersey-type" barriers represents a better balance between reducing delays and reducing work area crashes. What probably can be done is to provide escape off-travel-lane spaces wherever possible (which also can serve to get disabled vehicles off the roadway). This can be done by offsetting the concrete barriers at intervals and marking the distance to the next location. This process was done by the Illinois State Toll Highway Authority at some of their construction sites.

What did not appear to be an issue was traffic speeds through the working area except possibly in the immediate area of the construction. At this point, reduced speeds were not needed so much to protect workers from drivers, but rather to allow drivers more time to react to others distracted by the work. The use of concrete barriers separating workers from motorists appeared to provide more than ample protection.

## Table 28
## Selected Characteristics of At-Fault Drivers

| | Severity of Crash | | Location | | | | All Crashes | | Statewide |
|---|---|---|---|---|---|---|---|---|---|
| | Injury | PDO | Approach | Taper | Work Area | Exit | Frequency | Percent | Workzone* |
| **Sex of Driver** | | | | | | | | | |
| Female | 6 | 19 | 6 | 4 | 15 | 0 | 25 | 24.3% | 32.4% |
| Percent of At-Fault | 24.0% | 76.0% | 24.0% | 16.0% | 60.0% | 0.0% | | | |
| Male | 16 | 56 | 16 | 13 | 42 | 1 | 72 | 69.9% | 63.1% |
| Percent of At-Fault | 22.2% | 77.8% | 22.2% | 18.1% | 58.3% | 1.4% | | | |
| N/S | 1 | 5 | 1 | 1 | 4 | 0 | 6 | 5.8% | 4.5% |
| Percent of At-Fault | 16.7% | 83.3% | 16.7% | 16.7% | 66.7% | 0.0% | | | |
| **Age Group** | | | | | | | | | |
| Less than 21 years | 4 | 14 | 5 | 3 | 10 | 0 | 18 | 17.5% | 16.2% |
| Percent of At-Fault | 22.2% | 77.8% | 27.8% | 16.7% | 55.6% | 0.0% | | | |
| 21-25 | 2 | 13 | 5 | 1 | 9 | 0 | 15 | 14.6% | 13.5% |
| Percent of At-Fault | 13.3% | 86.7% | 33.3% | 6.7% | 60.0% | 0.0% | | | |
| 26-64 | 16 | 37 | 9 | 9 | 34 | 1 | 53 | 51.5% | 64.2% |
| Percent of At-Fault | 30.2% | 69.8% | 17.0% | 17.0% | 64.2% | 1.9% | | | |
| 65 and older | 1 | 9 | 2 | 3 | 5 | 0 | 10 | 9.7% | 6.1% |
| Percent of At-Fault | 10.0% | 90.0% | 20.0% | 30.0% | 50.0% | 0.0% | | | |
| Not Stated | 0 | 7 | 2 | 2 | 3 | 0 | 7 | 6.8% | 5.5% |
| Percent of At-Fault | 0.0% | 100.0% | 28.6% | 28.6% | 42.9% | 0.0% | | | |
| **Vehicles Involved** | | | | | | | | | |
| One | 3 | 13 | 2 | 1 | 12 | 1 | 16 | 15.5% | 19.9% |
| Percent of At-Fault | 18.8% | 81.3% | 12.5% | 6.3% | 75.0% | 6.3% | | | |
| Two | 13 | 56 | 16 | 13 | 30 | 0 | 69 | 67.0% | 68.7% |
| Percent of At-Fault | 18.8% | 81.2% | 23.2% | 18.8% | 43.5% | 0.0% | | | |
| 3 or More | 7 | 11 | 5 | 3 | 10 | 0 | 18 | 17.5% | 11.4% |
| Percent of At-Fault | 38.9% | 61.1% | 27.8% | 16.7% | 55.6% | 0.0% | | | |
| Total | 23 | 80 | 23 | 18 | 61 | 1 | 103 | 100.0% | |
| Overall Percent, At-Fault | 22.3% | 77.7% | 22.3% | 17.5% | 59.2% | 1.0% | | | |

*Based on 1994 and 1995 crashes coded "workzone" by police.

An examination of the narratives on the crash reports suggested that a possible contributor to crashes occurring in the approach and taper was higher speeds. Although the driver may have been within a commonly accepted tolerance for the given speed limit, e.g., up to 70 mph in a 65 mph zone, the speed limit itself may have been too high given traffic conditions leading to the zone. Given that approximately 40% of the crashes in this study occurred on the approach and taper, more specific attention needs to be given to driver behavior at these locations. Moreover, crashes in the approach and taper were more likely to result in injuries which suggested that speed may have played a role.

Although reducing the speed limit might appear to be a convenient answer, without providing an external stimulus for the motorist to slow, the likelihood of the decreased limit being obeyed may be low (Graham, Migletz, and Harwood 1993). Additional attention can be given to other traffic calming devices that have been used including rumble strips, decreasingly separated painted lines perpendicular to the roadway, and speed readout devices as examples.

However, the start of the lowered speed zones needs to be flexible instead of established simply according to traffic control standards. Where traffic is light, reduced speeds should be occurring within a short distance (several hundred meters or less) prior to a taper or lane shift. As traffic increases and queuing begins, then speed reduction needs to occur well before the start of the queue thereby giving drivers enough time to slow for the queue. Increasing the number of portable message boards and using them to set speed limits on a variable basis could prove beneficial.

That older drivers are also more likely to be involved in collisions at the taper and within the work area than other age groups may suggest a need to simplify the driving tasks. The use of arrow boards, and perhaps even merge markings on the pavement could help provide guidance. However, the number of PCR's from the special reporting was not large enough to disaggregate data further than shown in Table 28. Certainly, more information on collisions involving older drivers in workzones, especially related to their location in the workzone when involved, would be valuable.

Lastly, the large number of sideswipe collisions apparently resulting from failure to yield in the taper indicate a need to better understand merging behavior and why it leads to harmful consequences. This refusal to merge is an important issue. It not only sets the stage for crashes at the merge itself, but may lead to irritation or anger on the part of the "harmed" driver. Current research directed toward aggressive driving is suggesting that anger often plays an important role in dangerous driving behavior. Refusal by motorists to allow merging, perhaps because they believe they are "in the right," also suggests a need to require an alternate merge (including signs establishing such requirement). As with reducing speed limits prior to the working areas, control of merging will need to be backed by adequate enforcement. The issues related to early versus late merging, especially under congested conditions need further study. This effort is especially important given some recent findings by Byrd, *et al.* (1999) in a study of Pennsylvania workzones which suggested that having motorists proceed in all lanes to the merge point was a more efficient method of handling merging vehicles than other methods.

The finding that more attention needs to be given outside the working area to speeds and driver behavior is contrary to what tends to be the prevailing enforcement philosophy, that enforcement must be done in the working area (and according to resident engineers who were asked, the construction area is the area most likely to see a police officer who also is using radar). Yet, given the lack of severity of crashes and the manner of crashes, enforcement, especially of workzone speeds, within the working area may not be as effective as enforcement concentrating on the taper and approach sections. However, the need for enforcement also means that police must have adequate and safe areas from which to work. While the location behind the barricades marking the taper may be adequate (assuming that police vehicle emergency lighting is not used so as not to attract gaping), a suggestion is that during establishing the TCP one or more safe, temporary, off-the-road locations be created for police as well as disabled motorist's use.

**IMPORTANT FINDINGS**

1. Of those external contributing elements, interference from traffic control devices or problems with the devices, and construction activity and equipment accounted for 33% of the crashes.
2. Crashes outside the work area are more likely to result in an injury; the most common manner of collision is rear-end when work is in progress, but not when workers were not present.
3. Driver actions other than speeding apparently contributed to most of the crashes.
4. Within the working area crashes resulted from driver errors and were linked to narrow lane, lack of escape, and distractions from work in progress.
5. Outside the working area, changes suggested include making alternate merge mandatory, and reducing the speed (with enforcement) prior to the taper.
6. Driver refusal to merge is an ongoing problem which needs further research and proposals for correction.
7. There is a need to identify on the crash report that a crash occurred in a workzone and the exact location of that crash, at least as related to the four sections of the workzone.
8. Older drivers may have problems negotiating workzones, especially through the taper and work area. This population and their driving behavior at these locations needs further study.

## 6. Analysis of Workzone Traffic Control Devices Effectiveness

There are many contributing factors which may influence the crash rate at a given workzone including roadway geometry and characteristics, traffic and environmental conditions, and types of traffic control devices used. Because various types of traffic control devices influence workzone crash rates differently, it is important to identify the devices or combination of devices that are most effective at reducing crash rates. In this chapter, linear regression and hypothesis testing are used to assess the change in crash rates at a given workzone with respect to specific traffic control devices. The examination is done through the use of models which examine the contribution of various independent variables, e.g., concrete barriers, to the change in crashes. Where combinations of traffic control devices are examined, separate models are designed to avoid interaction effects, i.e., one model cannot examine both a combination of barrels and barriers and barrels and concrete barriers because the barrels are common to both combinations and be causing all of the effects. In addition, the models examine conditions as existed in actual workzones. No experimental conditions were used.

Some results from the statistical analysis of changes in crash rates before work began and when work was in progress included:

- The crash rate prior to the start of the work has the largest, significant effect on the amount of increase in crash rates.
- Posted speed limit signs, flashing arrow signs and flagger are effective at reducing overall increase in rate.
- Drums, concrete barriers, barricades and rumble strips individually or in combination appear to accentuate the increase.
- None of the traffic control devices (drums, concrete barriers, etc.) individually or jointly have a statistically significant effect on the changes.

### Data Collection

From the IDOT computerized crash database, workzone crashes (fatality, injury and PDO) were extracted for the year 1995 (when the workzone existed) and 1994 (before the construction started). Crashes per million vehicle miles (Crash/MVM) were computed based on the average daily traffic (ADT) (provided by the Office of Planning and Programming at IDOT), and length and duration of the workzone. Computations were done for sites under construction in 1995 and the same sites for 1994. The method of selecting length and duration followed the methodology described in Chapter 3. As a result, the crash rate is expressed in terms of million vehicle miles traveled (MVM).

$$\text{Crash Rate (MVM)} = \frac{\#\text{ of Crashes} * 10^6}{L * D * ADT}$$

where:

L - length of the workzone
D - duration, in days, of the workzone
ADT - average daily traffic

The types of traffic control devices used at each of the workzones were obtained from the workzone construction plans, which are kept on record at the IDOT District offices. All traffic control devices used at a given workzone must conform to the Special Provisions, Traffic Control Standards, Traffic Specifications and the *Illinois Manual on Uniform Traffic Control Devices for Streets and Highways* (IL-MUTCD). A list of devices encountered during the data collection effort appear in Appendix D.

**Compilation of Data**

The overall crash rates (fatality, injury, PDO) are listed in Table 29 for 21 workzone sites including seven Interstate highways and 14 other roadways which included both two-lane and four-lane configurations across nine counties. Three sites experienced a reduction in crash rate (negative change), two sites had no change (crash rate change of 0.00) and 16 sites had an increase in crash rates (positive change) during the life of the workzone.

**Table 29**
**Overall Crash Rates Per Million Vehicle Miles (Crash/MVM)**

| County | Route Number | Mileposts | Crashes | 1994 Crash Rate Before Construction (Crash/MVM) | 1995 Crash Rate During Workzone (Crash/MVM) | Change in Crash Rate (Crash/MVM) |
|---|---|---|---|---|---|---|
| Champaign | US 45 | 7.66 - 14.37 | 21 | 2.32 | 3.74 | 1.42 |
| Cook | US 12 | 19.03 - 29.39 | 453 | 4.09 | 5.05 | 0.96 |
| | IL 43 | 16.31 - 17.12 | 175 | 6.34 | 7.33 | 0.99 |
| | US 45 | 40.40 - 42.66 | 171 | 6.74 | 7.73 | 0.99 |
| | I-57 | 46.00 - 54.22 | 257 | 0.88 | 1.40 | 0.52 |
| | IL 58 | 11.00 - 14.48 | 127 | 5.67 | 5.37 | -0.30 |
| | IL 62 | 5.47 - 9.62 | 93 | 5.75 | 3.78 | -1.97 |
| | IL 72 | 6.86 - 8.55 | 213 | 10.53 | 10.53 | 0.00 |
| | I-94 | 52.81 - 74.67 | 100 | 3.08 | 4.22 | 1.14 |
| DuPage | IL 19 | 16.90 - 18.35 | 82 | 6.10 | 6.06 | -0.04 |
| | US 34 | 16.14 - 17.33 | 182 | 12.10 | 14.45 | 2.35 |
| Kane | IL 72 | 13.40 - 22.85 | 48 | 0.96 | 8.66 | 7.70 |
| Lake | IL 83 | 4.41 - 12.30 | 210 | 4.41 | 6.85 | 2.44 |
| Madison | I-55 | 10.50 -16.86 | 76 | 0.45 | 1.38 | 0.93 |
| | I-270 | 10.61 - 14.67 | 24 | 0.73 | 1.25 | 0.52 |
| Peoria | US 150 | 22.61 - 28.85 | 288 | 42.24 | 48.28 | 6.04 |
| Sangamon | I-55 | 94.07 - 99.76 | 81 | 2.08 | 4.95 | 2.87 |
| Will | US 30 | 16.71 - 30.53 | 83 | 4.37 | 5.18 | 0.81 |
| | US 52 | 3.82 - 8.16 | 185 | 8.12 | 8.12 | 0.00 |
| | I-55 | 52.13 - 69.40 | 261 | 0.70 | 1.11 | 0.41 |
| | I-80 | 37.51 - 47.86 | 91 | 1.39 | 2.05 | 0.66 |
| **Average** | | | | **6.15** | **7.50** | **1.35** |
| **Adjusted Avg.** | | | | **4.52** | **5.29** | **0.77** |

The change in crash rate in Table 29 ranges from -1.97 per MVM to 7.70 per MVM with an average change in crash rate increase of 1.35 per MVM and a variance of 4.49. If the highest two changes in crash rate (*i.e.*, 7.70 per MVM in Kane County and 6.04 per MVM in Peoria County) are disregarded, the adjusted average crash rate would be equal to 0.77 per MVM and a variance of 1.18.

After noting that the two highest rates occurred on non-limited access roadways, it seemed appropriate to group the sites by roadway type to measure the effect of the roadway type on both average crash rate and variance. Table 30 shows that non-limited access roadways exhibit a higher average change in crash rate and variance (*i.e.*, 1.53 crashes per MVM with a variance of 6.46) than Interstates (*i.e.*, 1.01 crashes per MVM and a variance of 0.74). Disregarding the highest two crash rates which were on the non-limited access roadways would yield an adjusted average change in crash rate of 0.64 crashes per MVM with a variance of 1.47.

The Interstate roadways have a higher average change in crash rate than non-limited access roadways, but a variance of approximately one half smaller than that of the other roadways. The higher average change in crash rate may be due to many factors such as bigger traffic volumes, higher vehicle speeds and congestion which collectively may contribute to more crashes on average than on non-limited access roads. However, the smaller variance seems to indicate that Interstate roadway crashes occur with a more consistent pattern than on non-limited access roads. This may be due to the relative uniformity of Interstate highways compared with the highly hazardous environment in which non-limited access roadway workzones reside. Typically, the traffic on non-Interstate type roadways is more affected by factors as intersecting roadways and turning movements which may explain the larger variance in crash occurrences.

**Table 30**
**Analysis of Crash Rate Variance by Type of Roadway**

| Type of Roadways | Overall Change in Crash Rates (Crash/MVM) | | | |
|---|---|---|---|---|
| | Minimum | Maximum | Average | Variance |
| All types | -1.97 | 7.70 | 1.35 | 4.49 |
| Interstate | 0.41 | 2.87 | 1.01 | 0.74 |
| Non-limited Access | -1.97 | 7.70 | 1.53 | 6.46 |
| *Adjusted Non-limited Access* | *-1.97* | *2.44* | *0.64* | *1.47* |

Tables 31, 32 and 33 list crash rates for the same sites by type of collision. Only the highest three changes in average crash rate in collision types (*i.e.*, rear-end, sideswipe-same direction and collision with objects) are presented. The average changes in crash rate for other types of collisions were small and cannot be used to perform analysis for statistical differences.

The three tables (31 through 33) also show the average change in crash rates for each collision type by roadway. The larger change in rear-end crash rate on Interstate highways (0.65 per MVM vs. 0.45 per MVM on other roadways) may be attributed, for example, to the lack of escape.

Table 31
Rear-end Crash Rates

| County | Route Number | 1994 Crash Rate Before Construction (Crash/MVM) | 1995 Crash Rate During Workzone (Crash/MVM) | Change in Crash Rate (Crash/MVM) |
|---|---|---|---|---|
| Champaign | US 45 | 0.89 | 1.96 | 1.07 |
| Cook | US 12 | 1.43 | 2.28 | 0.85 |
| | IL 43 | 2.87 | 3.21 | 0.34 |
| | US 45 | 3.75 | 3.66 | -0.09 |
| | I-57 | 0.21 | 0.62 | 0.41 |
| | IL 58 | 3.13 | 2.79 | -0.34 |
| | IL 62 | 3.89 | 2.44 | -1.45 |
| | IL 72 | 4.85 | 4.86 | 0.01 |
| | I-94 | 1.18 | 2.19 | 1.01 |
| DuPage | IL 19 | 2.93 | 2.52 | -0.41 |
| | US 34 | 5.38 | 6.72 | 1.34 |
| Kane | IL 72 | 0.96 | 2.41 | 1.45 |
| Lake | IL 83 | 1.79 | 3.63 | 1.84 |
| Madison | I-55 | 0.07 | 0.65 | 0.58 |
| | I-270 | 0.10 | 0.31 | 0.21 |
| Peoria | US 150 | 19.78 | 29.00 | 9.22 |
| Sangamon | I-55 | 0.49 | 2.20 | 1.71 |
| Will | US 30 | 2.06 | 3.00 | 0.94 |
| | US 52 | 3.20 | 3.51 | 0.31 |
| | I-55 | 0.21 | 0.45 | 0.24 |
| | I-80 | 0.43 | 0.83 | 0.40 |
| **Overall Average** | | **2.84** | **3.77** | **0.93** |
| **Adjusted Avg.** | | **1.99** | **2.51** | **0.52** |
| **Interstate Avg.** | | **0.38** | **1.03** | **0.65** |
| **Non-limited Access Avg.** | | **2.85** | **3.30** | **0.45** |

**Table 32**
**Sideswipe-same Direction Crash Rates**

| County | Route Number | 1994 Crash Rate Before Construction (Crash/MVM) | 1995 Crash Rate During Workzone (Crash/MVM) | Change in Crash Rate (Crash/MVM) |
|---|---|---|---|---|
| Champaign | US 45 | 0.00 | 0.18 | 0.18 |
| Cook | US 12 | 0.50 | 0.80 | 0.30 |
| | IL 43 | 0.44 | 0.59 | 0.15 |
| | US 45 | 0.45 | 0.68 | 0.23 |
| | I-57 | 0.21 | 0.24 | 0.03 |
| | IL 58 | 0.30 | 0.34 | 0.04 |
| | IL 62 | 0.26 | 0.05 | -0.21 |
| | IL 72 | 0.89 | 0.81 | -0.08 |
| | I-94 | 0.93 | 1.35 | 0.42 |
| DuPage | IL 19 | 0.52 | 0.49 | -0.03 |
| | US 34 | 1.01 | 1.34 | 0.33 |
| Kane | IL 72 | 0.00 | 1.44 | 1.44 |
| Lake | IL 83 | 0.54 | 0.12 | -0.42 |
| Madison | I-55 | 0.11 | 0.22 | 0.11 |
| | I-270 | 0.05 | 0.16 | 0.11 |
| Peoria | US 150 | 2.18 | 3.35 | 1.17 |
| Sangamon | I-55 | 0.24 | 0.98 | 0.74 |
| Will | US 30 | 0.00 | 0.19 | 0.19 |
| | US 52 | 0.35 | 0.70 | 0.35 |
| | I-55 | 0.10 | 0.22 | 0.12 |
| | I-80 | 0.29 | 0.38 | 0.09 |
| **Overall Average** | | **0.44** | **0.69** | **0.25** |
| **Adjusted Avg.** | | **0.36** | **0.56** | **0.20** |
| **Interstate Avg.** | | **0.27** | **0.50** | **0.23** |
| **Non-limited Access Avg.** | | **0.40** | **0.59** | **0.19** |

**Table 33**
**Collision with Object Crash Rates**

| County | Route Number | 1994 Crash Rate Before Construction (Crash/MVM) | 1995 Crash Rate During Workzone (Crash/MVM) | Change in Crash Rate (Crash/MVM) |
|---|---|---|---|---|
| Champaign | US 45 | 0.89 | 0.36 | -0.53 |
| Cook | US 12 | 0.26 | 0.40 | 0.14 |
| | IL 43 | 0.40 | 0.42 | 0.02 |
| | US 45 | 0.14 | 0.63 | 0.49 |
| | I-57 | 0.30 | 0.42 | 0.12 |
| | IL 58 | 0.13 | 0.30 | 0.17 |
| | IL 62 | 0.21 | 0.26 | 0.05 |
| | IL 72 | 0.57 | 0.58 | 0.01 |
| | I-94 | 0.72 | 0.38 | -0.34 |
| DuPage | IL 19 | 0.24 | 0.24 | 0.00 |
| | US 34 | 0.00 | 0.34 | 0.34 |
| Kane | IL 72 | 0.00 | 0.96 | 0.96 |
| Lake | IL 83 | 0.71 | 0.42 | -0.29 |
| Madison | I-55 | 0.22 | 0.31 | 0.09 |
| | I-270 | 0.52 | 0.67 | 0.15 |
| Peoria | US 150 | 1.34 | 1.34 | 0.00 |
| Sangamon | I-55 | 1.10 | 1.34 | 0.24 |
| Will | US 30 | 0.50 | 0.31 | -0.19 |
| | US 52 | 0.13 | 0.44 | 0.31 |
| | I-55 | 0.22 | 0.32 | 0.10 |
| | I-80 | 0.29 | 0.49 | 0.20 |
| **Overall Average** | | **0.42** | **0.52** | **0.10** |
| **Interstate Avg.** | | **0.48** | **0.56** | **0.08** |
| **Non-limited Access Avg.** | | **0.39** | **0.50** | **0.11** |

The average change in rear-end crash rate is the highest (0.93 per MVM), followed by the sideswipe, same direction (0.25 per MVM). Disregarding the seemingly high rear-end and sideswipe-same direction 1995 crash rates at US 150 in Peoria County, the adjusted average changes in rates would respectively be equal to 0.52 per MVM and 0.20 per MVM. On the other hand, the seemingly higher change in collision-with-object crash rate on non-limited access roadways (0.11 per MVM vs. 0.08 per MVM on Interstate highways) illustrates the increased hazard of workzones on these lower-level roadway types.

Initially, there was a concern that weather and light conditions might have played an important role with the increase in workzone crash rates. Weather and light conditions at the 21 sites are listed in Table 34 for the two periods. It appears that this hypothesis can be rejected. The percentages of rain and clear weather, light and dark conditions are similar in general at the time of the crashes both before construction and during the workzone. The table shows that the weather conditions at the time of the crash were more favorable during the workzone than before construction (14.4% rainy conditions vs. 19.2% before construction). Given that the frequency of crashes generally increases in wet weather, the relatively drier periods while the workzones were in place possibly kept the increases in crashes lower than otherwise might have occurred.

**Table 34**
**Analysis of Weather and Light Conditions**

| | Weather Conditions | | | Light Conditions | | |
|---|---|---|---|---|---|---|
| | Clear | Rainy | Other | Light | Dark | Other |
| Before Construction | 79.6% | 19.2% | 1.2% | 75.7% | 11.6% | 12.7% |
| During Workzone | 83.4% | 14.4% | 2.2% | 76.7% | 10.0% | 13.3% |

## Regression Models

### Variables Used and the Models

To better understand the changes in crash rates the focus is placed on establishing causal relationships between types of traffic control devices used and crash rates. This understanding can be aided by a regression analysis which examines the relationship between external factors (independent variables) and the outcome (dependent variable). The relationship is expressed by a starting point or intercept which shows the outcome even when all independent variables have a value of zero and a line which represents the effect of the coefficients or parameter estimates for the independent variables. A general expression, called a "model" is:

$$Y=a+b_1X_1+b_2X_{2+}...$$

where:

a is the intercept, and

$b_1$ and $b_2$ are parameter estimates for the independent variables $X_1$ and $X_2$.

For this analysis, a number of linear regression models were developed by using as independent variables the traffic control devices (or combination of devices) and the crash rate before the beginning of construction. The dependent variable was the crash rate when the workzone was in place.

The traffic control devices selected for analysis because they were shown as TCD's on the construction plans include: drums, vertical panels, concrete barriers, barricades, cones, pavement markings (type III), advance warning signs, workzone speed limit sign, Do Not Pass sign, variable message sign, flashing arrow sign, flagger, and rumble strips. Table 35 lists these devices and shows that one or more of them is used at each of the 21 sites. Rumble strips is the least commonly used control device, present at only two workzone sites, while pavement markings (type III) and advance warning signs are used at all 21 sites.

Regression is performed as models which include sets of independent variables. The first model treats each variable separately. Subsequent models reflect combinations of TCD's. In the regression models for this chapter, each type of traffic control device or combination of devices is represented by a dummy variable. The dummy variable takes the value one (1) if the device (or combination of devices) is used and zero (0) if it is not. The general form of the model is given by:

$$WZCR = \beta_0 + \beta_{BCR}\,(BCR) + \beta_i\,(TCD_i)$$

where:

WZCR: is the crash rate during the workzone
BCR: is the crash rate before the beginning of construction
$TCD_i$: is the $i^{th}$ device or combination of devices used at workzone
= 1 when used
= 0 when not used
$\beta_0$: intercept
$\beta_{BCR}$, $\beta_i$: respective parameter estimates of the independent variables

For example, model 2 in Table 36 is of the form:

$$WZCR = 0.32 + 1.10\,(BCR) + 1.69\,(\text{combination of drums and barricades})$$

If the crash rate (BCR) before the beginning of construction is available and the combination of drums and barricades is used (equal to 1) at the workzone, then the workzone crash rate (WZCR) can be derived using the model above. The first value shown in each cell is the intercept or parameter estimate. The value in parentheses represents the *t*-statistic. This statistic is the result of testing the likelihood of the value being different from zero. Given the number of sites for each variable, a value of ± 1.96 would be required at the 0.05 level (also called the "95% confidence level"). A *t*-statistic which exceeded this level means that there would be 5 or less chances in 100 that the computed statistic was equal to zero.

## Results of the Analysis

Using all 21 sites, the general form of the linear regression model is run for the traffic control devices or combination of devices and the results are presented in Table 36. All coefficients are shown to indicate both the direction of effect, i.e., a positive coefficient means that when it was present crashes increased and a negative one means that crashes decreased, and to show which ones provided significant contributions to the change. The results indicate that the consistently

**Table 35**
**Traffic Control Devices Used**

| County | Route Number | Traffic Control Device Used[1] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **100** | **101** | **103** | **105** | **107** | **108** | **200** | **209** | **217** | **400** | **501** | **503** | **600** |
| Champaign | US 45 | x | | | x | | x | x | x | | | x | x | |
| Cook | US 12 | | | x | x | | x | x | x | x | x | | | |
| | IL 43 | | | | x | | x | x | x | | | | | |
| | US 45 | | | x | x | | x | x | x | x | | x | | |
| | I 57 | x | x | | | | x | x | x | | | | | |
| | IL 58 | | | | x | x | x | x | x | | | x | x | x |
| | IL 62 | | | | x | | x | x | | x | | x | x | |
| | IL 72 | x | x | x | x | x | x | x | x | | | | | |
| | I 94 | x | | x | | | x | x | x | | x | x | | |
| DuPage | IL 19 | | | | x | | x | x | x | | | | | |
| | US 34 | | x | | x | | x | x | x | | | | | |
| Kane | IL 72 | x | x | | x | x | x | x | x | | | | | |
| Lake | IL 83 | x | x | | x | x | x | x | x | | | | | |
| Madison | I 55 | x | x | | | | x | x | x | | | | | |
| | I 270 | x | x | | | | x | x | x | | | | | |
| Peoria | US 150 | x | | | | x | x | x | x | | | x | x | |
| Sangamon | I 55 | | | x | x | | x | x | x | | | | | |
| Will | US 30 | x | x | | x | x | x | x | x | | | x | x | |
| | US 52 | x | | | | x | x | x | x | | | x | x | x |
| | I 55 | x | x | | | | x | x | x | | | | x | |
| | I 80 | x | | x | | | x | x | | | | | x | |

[1] **Traffic control devices**: 100 = drums; 101 = vertical panels; 103 = concrete barriers; 105 = barricades; 107 = cones; 108 = pavement markings (type III); 200 = advance warning signs; 209 = workzone speed limit sign; 217 = do not pass sign; 400 = variable message sign; 501 = flashing arrow signs; 503 = flagger; 600 = rumble strips. See Appendix D for a complete list.

statistically significant independent variable is the crash rate before the beginning of construction. The parameter estimate ($\beta_{BCR}$) always has a high value of the $t$-statistic (shown inside parentheses). In model 1, this parameter takes the value 1.20 with a $t$-statistic of 27.12. This suggests that the crash rate during the workzone will increase on average by 20% from the crash rate before the beginning of construction, if traffic control devices are not used at all during the life of the workzone. This can be verified by looking at the average crash rate before the beginning of construction (6.15 crashes per MVM) and during the operation of the workzone (7.50 per MVM) in Table 29 (page 57). It corresponds to a 22% increase in crash rate. Model 1 in Table 36 suggests that posted workzone speed limit signs, flashing arrow signs and flagger

**Table 36**
**Regression Models to Predict Overall Crash Rates at Workzones**

| Independent Variables | Dependent Variable: Workzone Crash Rate for All 21 Sites | | | | |
|---|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 3** | **Model 4** | **Model 5** |
| Intercept | -2.80 (-2.22) | 0.32 (0.56) | 0.87 (1.53) | 0.87 (1.58) | 1.00 (1.83) |
| Crash rate before workzone | 1.20 (27.12)* | 1.10 (22.97)* | 1.09 (21.32)* | 1.09 (21.62)* | 1.12 (21.11)* |
| 100 = Drums | 4.31 (4.03)* | | | | |
| 103 = Concrete barriers | 1.65 (1.77)[1] | | | | |
| 105 = Barricades | 3.58 (3.44)* | | | | |
| 209 = Workzone speed limit | -0.87 (-3.70)*[1] | | | | |
| 501 = Flashing arrow sign | -1.79 (-1.94) | | | | |
| 503 = Flagger | -1.74 (-1.95) | | | | |
| 600 = Rumble strips | 1.74 (1.25) | | | | |
| Drums and barricades | | 1.69 (1.73) | | | |
| Drums and workzone speed limit | | | -0.12 (-0.56) | | |
| Concrete barriers and workzone speed limit | | | | -0.17 (-0.84) | |
| Flashing arrow sign and flagger | | | | | -1.39 (-1.36) |
| $R^2$ | 0.987 | 0.967 | 0.962 | 0.963 | 0.965 |

Note: value in parentheses refers to the *t* value with a *df*=20. Those values with an asterisk (*) indicate a statistically significant factor at the 0.05 (95% confidence) level.
[1] For Interstate highways alone, only concrete barriers and workzone speed limit have significant parameters of +3.64 and +2.69, but the Crash Rate Before parameter provides no contribution.

are effective at reducing workzone crash rates (negative parameter estimate). Signs requiring speed reduction generally help reduce vehicle speed variance inside the workzone, which in turn translates into fewer crashes.

The workzone speed limit parameter estimate of (-0.87) is the most statistically significant among the three, with a *t*-statistic of (-3.70). This result suggests that the crash rate during the workzone would be reduced by 0.87 when workzone speed limit signs are present.

While flashing arrow signs and flaggers have a potential effect at reducing workzone crash rate if they were used, with respectively a parameter estimate of (-1.79) and (-1.74), the *t*-statistics are not significant. The direction of effect supports anecdotal evidence from resident engineers and findings in the literature which have reported that drivers are much more inclined to respond to dynamic signing (flashing arrow vs. static signs) and physical intervention (flagger). Flashing arrow signs are particularly effective at night because they can be seen far away.

Drums, concrete barriers, barricades and rumble strips in Model 1 seem to contribute to increase the crash rate during the workzone (positive parameter estimate). The *t*-statistic for concrete barriers and rumble strips is not significant at the 95% confidence interval with both $t$-statistics less than 1.96. However, drums and barricades have significant $t$-statistics and the highest effect on workzone crash rates parameter estimates of 4.31 and 3.58 respectively.

Drums and barricades are usually used for delineation to guide traffic through the workzone. They can be a source of confusion to drivers, particularly when used on non-limited access streets, which probably explains the higher effect they have on workzone crash rates.

Conversely, concrete barriers cause less confusion, but are more intimidating. Drivers may perceive the lanes as narrower when going through a workzone with concrete barriers. Although, the $t$-statistic is not significant at the 95% confidence interval, we can argue that the smaller effect (parameter estimate of only 1.65) they have on workzone crash rates compared to drums and barricades is due to the fact that they are more effective at preventing some type of crashes. For example, concrete barriers are effective at protecting workers and/or pedestrians from the traveling traffic, which drums or barricades do not. They still have a beneficial effect on workzone crash rate because they constrain the roadway inside the workzone (no escape available to the vehicles) converting probably head-on or pedestrian collisions into rear-end crashes and/or collision with objects.

The remaining models try to evaluate the effect of combinations of traffic control devices in order to identify those that help reduce workzone crash rates (*i.e.*, combination of traffic control devices which would result in a negative parameter estimate). In model 2 (see Table 36), the effect of only drums and barricades on the workzone crash rate is evaluated. There, the dummy variable takes the value 1 only if drums *and* barricades are used at a given workzone, and 0 if *one* or *both* traffic control devices are not used. The results are similar to those of model 1, but with a smaller parameter estimate for the combination of 1.69 and a $t$-statistic of 1.73 (which is not significant at the 95% confidence interval).

More interestingly, when the combination of drums and workzone speed limit (Model 3), concrete barriers and workzone speed limit (Model 4), and flashing arrow sign and flagger (Model 5) are evaluated, the results seem to indicate that the respective combinations might decrease the workzone crash rates. However, parameters for all three combinations could easily have occurred by chance. Therefore, without testing the use of such combinations, no conclusions can be drawn as to their effectiveness.

The results in Table 36 are derived using Interstate highways and other roadways combined. We need to be careful when presenting the above interpretation of the results, because some traffic control devices may be used more frequently on one type of roadway than on the other. For example, concrete barriers are more frequently used on Interstate highway workzones, while barricades are more frequently used on non-limited access roads.

Similar models as in Table 36 are run for each roadway type (*i.e.*, Interstate and non-limited access roads). Because the sample sizes were so small (seven for Interstate roadways and 14 for other types), the results of the regression modeling were highly variable. Formal discussion of individual contributions of independent variables is not pursued in this chapter. However, a study that included more of each roadway type might yield more consistent and useful results.

With the exception of concrete barriers and the workzone speed limit on Interstate highways, none of the other parameters contributed significantly to the model. What also is interesting about the "workzone speed limit" variable for Interstate highway is that the effect became positive instead of negative, the opposite direction to workzone speed limits for all roadway types combined. This result would suggest that a workzone speed limit on the Interstate highway would act to increase the crash rate. However, this result also might be an anomaly arising from the small sample. Results of that analyses appear in Appendix F.

During the initial search for workzone sites, it became evident that many workzone construction plans on record included only the Traffic Control Standards and not the Special Provisions (*i.e.*, describing traffic control devices actually used at a given workzone and changes made during the course of construction). This means that all of the models were being run against the stated standards, and did not reflect what types of controls may have been in place at the time of the crash. Including more sites in this analysis then would not have contributed more information because the types of TCD's and their distribution across the sites would have been identical.

**Table 37**
**Regression Models to Predict Rear-end Crash Rates at Workzones**

| | **Dependent Variable: Rear-end Crash Rate at Non-limited Access Road Workzones (14 sites)** | |
|---|---|---|
| **Independent Variables** | **Model 6** | **Model 7** |
| Intercept | -0.83 (-1.69) | -1.39 (-2.79)* |
| Crash rate before workzone | 1.46 (26.71)* | 1.43 (20.55)* |
| 100 = Drums | 2.44 (4.22)* | 1.47 (2.33)* |
| 103 = Concrete barriers | 1.71 (1.99) | |
| 209 = Workzone speed limit | -0.54 (-3.26)* | |
| 501 = Flashing arrow sign | -1.22 (-2.05) | |
| **$R^2$** | 0.99 | 0.98 |

Note: Asterisk (*) denotes significance at the 0.05 level where *df*=13, $t = 2.16$.

Instead, the focus is put on using the sample size of the 14 non-limited access workzones (listed in Table 29) and on analyzing the effectiveness of traffic control devices at reducing particular types of collisions. Because the highest average change in crash rate for collision types on non-limited access roads is rear-end (0.45 crashes per MVM, see Table 31), the analysis focuses on studying first the effect of some traffic control devices on rear-end crash rates on non-limited access road workzones. Two models are run and presented in Table 37.

Model 6 in Table 37 shows that drums and concrete barriers seem to increase rear-end crash rate at non-limited access road workzones. Both parameter estimates (respectively 2.44 and 1.71) have statistically significant *t*-statistics (respectively 4.22 and 1.99) at the 95% confidence interval. The higher effect of drums on rear-end crash rate should be expected due to the driver confusion as discussed earlier. Probably drivers driving through the workzone are hesitant (suddenly slowing down or turning into driveways or parking lots), which in turn might be the basis for rear-end crashes.

Model 6 also shows that workzone speed limit and flashing arrow signs tend to decrease rear-end crash rates. Both parameter estimates (respectively (–0.54) and (–1.22)) have statistically significant *t*-statistics (respectively (-3.26) and (-2.05) at the 95% confidence interval). Drivers are probably more inclined to respond to the flashing arrow sign because of its dynamic nature and also because it is usually located at the last possible merging point, thus motivating drivers to merge earlier. Typically, late merging vehicles cause stop and go conditions at the taper area, which in turn cause rear-end crashes.

On the other hand, drivers usually set their vehicle speed to what they perceive as safe and generally consider the speed limit sign's recommendation only when the prevailing conditions lend them to do so (*e.g.,* if it is rainy or foggy).

Model 7 in Table 37 evaluates the effect of only drums on rear-end crash rates on a non-limited-access roads. The results are similar to those in Model 6 with the exception that the parameter estimate, and therefore degree of effect, of the drums is smaller (1.47 vs. 2.44). In both models, the estimate is significant.

Similar models were run to test the effectiveness of traffic control devices at reducing the other two collision types (*i.e.,* sideswipe-same direction and collisions with objects). Only the variable, "crash rate before" contributed to the model. Contribution of the remaining parameters was not significant. The resulting tables appear in Appendix F. Probably, the low average change in crash rate for these types of crashes (0.19 per MVM and 0.11 per MVM - Tables 32 and 33) and the small sample size of non-limited access road workzones (14) contributed to the lack of statistical significance. Additionally, the $R^2$ are relatively low which indicates a relatively small contribution of the variables to the crash rates.

**Hypothesis Testing**

This section introduces hypothesis testing to evaluate the effect of a given traffic control device on the average change in workzone crash rates. The primary intent is to find out if a given traffic control device has a distinct effect on a given crash rate when it is used compared to when it is not. The average change in crash rate at workzones where the device is used is compared to the average change in crash rate when it is not used. This is expressed as follows:

$$H_0 : \mu_{(used)i} = \mu_{(not\text{-}used)i}$$
$$H_1 : \mu_{(used)i} \neq \mu_{(not\text{-}used)i}$$

where:

$\mu_{(used)}$ is the average change in crash rate when the $i^{th}$ TCD is used
$\mu_{(not\text{-}used)i}$ is the average change in crash rate when $i^{th}$ TCD is not used.

The statement $H_0 : m_{(used)i} = m_{(not\text{-}used)I}$ is called the *null hypothesis,* and
$H_1 : m_{(used)i} {}^1 m_{(not\text{-}used)i}$ is called the *alternative hypothesis.*

The null hypothesis is what we would like to reject after performing the hypothesis testing in order to claim that a particular traffic control device has a distinct effect on a given crash rate when it is used compared to when it is not. When the hypothesis is rejected, the change will be different than when the device was not used. The null hypothesis is rejected (or not) after computing the *t*-statistic ($t_0$) which compares the two average changes in crash rate (one when the traffic control device is used and when it is not). It is computed as follows:

$$t_0 = \frac{y_1 - y_2}{S_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where:

$n_1$ and $n_2$ are the sample sizes (*i.e.,* number of workzones where device is used or not ).
$y_1$ and $y_2$ are the sample average changes in crash rate,

$S_p^2$ is an estimate of the common variance computed as follows:

$$S_p^2 = \frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}$$

where:

$S_1^2$ and $S_2^2$ are the two individual sample variances.

Tables 38 and 39 summarize respectively the average change in overall and rear-end crash rates and variance when a given traffic control device is used and when it is not. These values are then used to compute the *t*-statistic ($t_0$). For example, in Table 38 the average change in overall crash rate when only drums are used is computed by using Table 35 (to identify workzones where drums are used) and Table 29 (to then get the actual change in crash rate for that workzone). As a result, $n_1$ is found to be equal to 13 (workzones where drums are used) and that $n_2$ is equal to 8 (workzones where drums are not used). Consequently, $y_1$ is found to be equal to 1.74 per MVM and $y_2$ is equal to 0.74 per MVM (respective average changes in crash rate as derived from Table 29). Finally, Tables 38 and 39 also list the minimum and maximum changes in crash rates for each respective sample (where a given traffic control is used and when it is not used) as derived from Tables 29 and 31.

**Table 38**
**Analysis of Overall Crash Rate per Type of Traffic Control Device**

| Type of Traffic Control Device | | Overall Crash Rates Difference | | | |
|---|---|---|---|---|---|
| | | Minimum | Maximum | Average | Variance |
| **Drums** | Used | 0.00 | 7.70 | 1.74 | 5.70 |
| | Not Used | -1.97 | 2.87 | 0.74 | 2.33 |
| **Concrete barrier** | Used | 0.00 | 2.87 | 1.10 | 0.92 |
| | Not Used | -1.97 | 7.70 | 1.46 | 6.04 |
| **Flashing Arrow Signs** | Used | -1.97 | 6.03 | 1.01 | 5.30 |
| | Not Used | -0.04 | 7.70 | 1.57 | 4.27 |
| **Flagger** | Used | -1.97 | 6.03 | 0.88 | 5.35 |
| | Not Used | -0.04 | 7.70 | 1.64 | 4.12 |

**Table 39**
**Analysis of Rear-end Crash Rate per Type of Traffic Control Device**

| Type of Traffic Control Device | | Rear-end Crash Rate Difference | | | |
|---|---|---|---|---|---|
| | | Minimum | Maximum | Average | Variance |
| **Drums** | Used | 0.01 | 9.22 | 1.36 | 5.86 |
| | Not Used | -1.45 | 1.71 | 0.24 | 1.07 |
| **Concrete Barrier** | Used | -0.09 | 1.71 | 0.65 | 0.46 |
| | Not Used | -1.45 | 9.22 | 1.05 | 5.79 |
| **Flashing Arrow Signs** | Used | -1.45 | 9.22 | 1.33 | 10.88 |
| | Not Used | -0.42 | 1.85 | 0.69 | 0.48 |
| **Flagger** | Used | -1.45 | 9.22 | 1.30 | 10.87 |
| | Not Used | -0.42 | 1.85 | 0.71 | 0.52 |

Table 40 lists the results of the hypothesis testing. In each case, the "null hypothesis," i.e., no difference between the two values, is to be rejected if the likelihood of the two values being similar is less than some value (x) times in 100 cases. This is usually expressed as a percent, 5%, or a decimal proportion, e.g. 0.05. Normally, a value of 5% or less is used. In the analyses of differences in contributions to workzones crashes, the *null hypothesis* was never rejected. The large variance in each case (in Tables 38 and 39) is a plausible explanation for the small values of $t_0$ (less than 1.729 which is the value of the $t$-statistic ($t_0$) at the 95% confidence interval and $n_1$

$+ n_2 - 2$ degree of freedom). The large variance is partly attributable to the relatively small sample size of selected workzones (where $n_1 + n_2 - 2$ is very small only equal to 19 in this report). This results in a large $S_p^2$ value.

However, the *null hypothesis* can be rejected at higher significance levels which range from 12% to 36%. For these intervals, the results indicate that using drums as opposed to other types of traffic control devices seem to increase the overall and rear-end crash rates (parameter estimates respectively equal to 1.055 and 1.232). Furthermore, although the use of flashing arrow signs and flaggers seem to decrease overall crash rates (a result that is consistent with the linear regression models findings), they seem to increase rear-end crash rates. This last finding is counter intuitive and should be cautiously interpreted as both the confidence interval and the sample size are very small.

**Table 40**
**Hypothesis Testing Results**

| **Type of Traffic Control Device** | | **Hypothesis Testing Results** | | | |
|---|---|---|---|---|---|
| | | $t_0$ | $t_{0.05, 19}$ | **Result at 95% Confidence Level** | **Significant at** |
| **Drums** | Overall | 1.055 | 1.729 | Cannot reject $H_0$ | 17.5% |
| | Rear-end | 1.232 | 1.729 | Cannot reject $H_0$ | 12.0% |
| **Concrete barrier** | Overall | -0.344 | 1.729 | Cannot reject $H_0$ | 36.0% |
| | Rear-end | -0.395 | 1.729 | Cannot reject $H_0$ | 34.0% |
| **Flashing Arrow Signs** | Overall | -0.578 | 1.729 | Cannot reject $H_0$ | 30.0% |
| | Rear-end | 0.686 | 1.729 | Cannot reject $H_0$ | 25.0% |
| **Flagger** | Overall | -0.791 | 1.729 | Cannot reject $H_0$ | 20.0% |
| | Rear-end | 0.631 | 1.729 | Cannot reject $H_0$ | 28.0% |

**IMPORTANT FINDINGS**

1. The average change in overall crash rates (fatality, injury, and PDO) from no workzone to workzone on Interstate highways is higher than the change on non-limited access roads, but the variance is approximately one half smaller than that of non-limited access roads.

2. The analysis is based on existing conditions without testing. Even where a parameter suggests that presence of a traffic control device may increase crashes, e.g. presence of rumble strips, this finding suggests that more research is needed to identify if indeed these initial findings are important. However, there remains the issue that testing the presence or absence of TCD's may also have liability implications. Because so many of the standards are spelled out in law through acceptance of the MUTCD, issues of liability need to be researched.

3. Given the relatively small sample available for analysis (seven Interstate highways and 14 non-limited access roadways), the following observations can be made:

    a. Posted speed limit signs are effective at reducing the increase in overall workzone crash rates.

    b. While flashing arrow signs and flaggers have a potential effect at reducing workzone crash rate if they were used, with respectively a parameter estimate of (-1.79) and (-1.74), the *t*-statistics are not significant.

    c. Some devices, such as the use of drums, may increase the occurrence of crashes, but their use is preferable to no devices because they reduce the severity and prevent encroachment into the area of work.

# 7. Site Visits and Video Observations

This chapter summarizes the discussions with the resident engineers of five sites visited in 1998 plus two additional sites in 1999, and formulates recommendations based on those discussions, and videotaped observations of the site layout and driver behavior. Where data were available, a discussion of crashes was included. This discussion relies on crash data collected by the appropriate police agency. In some cases, they are reports which were available to the Resident Engineers (RE), and in other cases, those specifically collected for the project.

Additionally, as a result of videotaping done at selected sites and a merge area on an Interstate roadway, an analysis of driver behavior on the approach and taper was possible. This analysis appears in Chapter 8 which treats speed and driver behavior and how these may affect safety at construction zones regardless of the traffic control devices in place.

## Sources of Crash Data for the Site Analyses

For the workzone along I-74, the RE had copies of the police crash reports (PCR) and provided copies of what he had received from the Illinois State Police (ISP) District. The RE used the reports to identify, where possible, elements of the traffic control plan (TCP) or traffic control devices (TCD) that may have contributed to crashes and could be changed. Actions by the RE are noted in the discussion below.

At several locations, the ISP District Commanders (or Sheriff), at the request of the project team, instructed their officers to record *all* crashes in any section of the workzone (including the approach, taper, working area, and exit). These reports appear to represent a comprehensive picture.

Another approach would be to visit each police agency responsible for reporting crashes at the workzone and extract and copy all reports filed for what appeared to be the entire workzone. Even with this method, crashes might be missed because the reporting officer failed to include a correct location, unless that officer also provided a narrative which suggested where the crash occurred.

The remainder of this chapter discusses each of seven sites in detail. It ends with a series of recommendations derived from the on-site visits.

**I-74 North of Woodhull and South of Route 81**

| | |
|---|---|
| Started | March, 1998 |
| Projected End | November 1, 1999 |
| Date of Visit | July 8, 1998 |
| Work Description | Pavement patching and resurfacing<br>Bridge rehabilitation and replacement |
| Length of Workzone | 8.75 miles |
| ADT 1995[14] | 13,200 vehicles (22% trucks) |
| IDOT District | 2 |

## Workzone Description

The Resident Engineer (RE) described the project as consisting of patching and resurfacing of the pavement and bridge rehabilitation and replacement. The pavement needed to be replaced because the ground was soft and potholes surfaced every time it rained, causing dangerous conditions.

The construction work started at 7 a.m. and ended at 4:30 p.m. six days a week and was described by the RE as "very heavy" on a daily basis. Driving through the workzone, the work intensity was found to be distractive because a great number of construction vehicles and trucks were circulating inside the work area or parked on the shoulders.

No queue build-ups were observed, even on Friday afternoons, being in general the most congested time, even with the relatively high truck percentage. The RE added that detours were not an option because affected communities strongly opposed them claiming that increased traffic was not acceptable.

## Layout and Traffic Control Plan (TCP)

The RE stated that the I-74 project did not have a layout and Traffic Control Plan (TCP) drawn because IDOT did not want to phase the layout of the Traffic Control Devices (TCD). As a result, the RE had to design the TCP and the type of TCD's to be used, which then were approved by the district traffic control supervisor. The TCP required the taper to be outlined by a series of drums and one arrow board indicating to drivers the direction of the merge. In addition, several other static signs warn of the merge along with a posted speed limit inside the workzone where the traffic in each direction is handled by an 11-foot lane with a two-foot shoulder. Vehicles are separated from the work area and the opposing traffic by concrete barriers. The traffic supervisor inspects the TCD on a biweekly basis, while the RE inspects it every day.

In general, the RE believed that the greater the number of warning signs used the less the attention they get from frequent users of the facility. However, the RE believes that Variable Message Signs (VMS) appear successful at attracting drivers' attention. Unfortunately, VMS

14 Average Daily Travel (ADT) values represent the most recent traffic counts available for the location.

were not used on this workzone because their cost was not budgeted. On other sites he worked, VMS were used only in emergency situations to warn of crashes or road closures but not as a routine everyday TCD.

The site also used off-duty police officers paid for by a fund IDOT has for the "hire back program." Typically, every workzone has a number of hours allocated to hire off-duty police during the fiscal year (ending June 30). Money allocated by the "hire back program" was used to hire, on an average of twice a week, off-duty officers. For this project, 460 hours are allocated in one fiscal year. After four months of operation, the RE had used all of the hours. Police officers generally park their cars with the emergency lights on to slow down traffic or use radar guns to give speeding tickets when reduced speed limits are posted. All of the enforcement is done in the working area.

**Crashes During Construction**

General discussion of crashes at the site. Since the beginning of the workzone, 20 crashes occurred, including one fatality (a copy of the PCR is filed at the East Moline District Office, which sends a copy to the RE for his file). The RE provided copies of eight police crash reports covering those occurring early in the project. Of the eight crashes, 7 involved trucks. the remaining one involved a rear-end collision between two cars within the working area. Trucks also represented seven of the 10 vehicles involved. In four cases, the crash occurred after the roadway was narrowed to one lane in anticipation of the cross-over, and the truck encroached on the soft shoulder, turning over. The one fatality resulted from this type of collision. The 11-foot lane just after the taper was perceived as too narrow by many as a result of the concrete barrier, a perception shared by the RE and those visiting the site when driving through it. Adding wider and stronger shoulders quickly solved the problem by making a wider lane, especially for trucks.

Four reports were taken after the police began attaching the supplemental report. In the first two, the shoulder again played a role, but from the diagram and narrative, it appears that the crash occurred further into the workzone than previous incidents. However, these reports still suggested that trucks need adequate maneuvering room. The remaining two reports appear to have been the result of driver inattention in that a slowing or stopping vehicle was struck from the rear. In one case, the precipitating driver stopped for a flagger when such was not required. This may have been either a lack of understanding of driving rules on the part of the driver, or it could have been improper flagging. Because no further investigation was done, this question cannot be answered.

Table 41 depicts information about the crash, the driver, vehicle, weather and light conditions at the time of the first 8 crashes. For most of the crashes, all elements were normal, e.g., "no defects," "not obscured." In one case, the rear trailer of a double bottom came unhitched and precipitated the event.

**Table 41**
**Crashes, Vehicles, Drivers, and Environment**

| Characteristic | Frequency | Characteristic | Frequency |
|---|---|---|---|
| **1. Crashes** | 8 | **6. Driver Condition** | |
| | | Normal physical condition | 7 |
| **2. Vehicles** | 10 | Fatigued | 2 |
| Trucks | 7 | Not stated | 1 |
| Passenger vehicles | 3 | **7. Driver Vision** | |
| **3. Weather Condition** | | Not obscured | 9 |
| Clear | 8 | Not stated | 1 |
| **4. Light** | | **8. Vehicle Status** | |
| Day | 3 | No defects | 7 |
| Night | 5 | Trailer coupling | 1 |
| **5. Location of Crash** | | Not stated | 2 |
| Approach and taper | 1 | | |
| Transition (two-way traffic) | 4 | | |
| Working area | 3 | | |

Table 42 shows that warning signs (TRFD[15]) were in place and that they were functioning correctly (TRFC). In the one case where the coding was "improper function," the narrative did not support the coding. This crash was the result of a vehicle defect, and could have occurred whether or not the workzone was in place.

Drivers were cited in 38% of the crashes, but improper lane use referred to semi-tractor units infringing on the shoulder with the shoulder playing a likely role in causing the loss of control. Only in one case was a driver cited for "too fast to avoid an accident," and the narrative does suggest that the driver entered the taper at a speed well in excess of the posted workzone speed. In the early analysis of the IDOT crash database only 10% of the crashes were attributed to driving too fast to avoid a crash. How many of those were for driving in excess of the posted limit is not known because of the lack of primary evidence (eyewitness observation, measurement) of speed violations.

Given the number of rear-end collisions in general within workzones, one could argue either that drivers are following too closely or inattentive driving is most important contributing factor and these violations should be the subject of enforcement. However, when police officers were observed at workzones, they generally were operating radar at the beginning of the zone.

---

15 TRFD is the code used for the Illinois Police Crash Report element, "Traffic Control Device," and TRFC is "Traffic Control Device Condition."

**Table 42**
**Driver Response to the Traffic Control Device Used And the Resulting Manner of Collision**

| Crash Element | Frequency |
|---|---|
| **1. TCD Used** | |
| No control | 1 |
| Warning signs | 6 |
| Other | 1 |
| **2. TCD Condition** | |
| No control | 1 |
| Functioning properly | 6 |
| Functioning improperly | 1 |
| **3. Driver (at-fault) Cited** | |
| None | 5 |
| Improper lane use | 2 |
| Too fast to avoid an accident | 1 |
| **4. Manner of Collision** | |
| Object | 3 |
| Overturned | 4 |
| Other | 1 |

In general, this project used TCD that appeared to be adequate and up-to-date. The TCP, and in particular the geometry of the roadway in the transition area, required changes to make the location safer.

Detailed discussion of the eight early crash reports. Shown most clearly on the first report for I-74 is the basis for what was noted earlier, that truck drivers came into the narrowed lane (eleven-foot) and lost control because of the truck wheels infringing on the soft shoulders. The driver also may have been going too fast to keep a good track for the rig once the vehicle entered the narrowed lanes. A similar event occurred in the second report. The narrative does not indicate whether or not speed was a factor, nor does it show where the driver was in relation to the end of the taper. However, given that the transition area prior to the crossover to two-way traffic is not long, an assumption can be made that this driver also had just entered the narrowed lanes and did not have time to track the vehicle correctly.

Reports 3 through 6 tell similar stories. Trucks, after entering the narrowed lanes drove onto the soft shoulder which caused the driver to lose control (in report number 6, it was the rear wheels of the tandem unit which ran off). In none of the reports did the reporting officer consider speed as a factor. Given the situation, a taper followed by a narrow, 11-foot lane bounded by a concrete barrier on one side and soft shoulder on the other, the truck driver would require time to ensure that his or her vehicle was tracking correctly on the lane. Higher speeds would have reduced time for the driver to correct tracking errors. These six reports led the RE to having the shoulders strengthened.

## Summary of the Film Findings

The filming at this site was done from an overpass looking into the taper of the workzone on August 3, 1998, at 5:30 p.m. (see Picture 1 in Appendix D). The video shows that the taper starts exactly where the on-ramp ends. This setup might lead to a number of sideswipe, same-direction collisions between the traffic on I-74 and the on-ramp flow. Indeed, a proportion of the vehicles disregarded the early warning signs and chose to merge closer to the taper at what appears to be high speeds. The issue of vehicle speeds approaching the merging area is considered in recommendations for changes in speed posting and enforcement as discussed in Chapter 8. It seems valuable to complete the lane reduction before the traffic on I-74 meets the traffic from the on-ramp and to equip the on-ramp with a ramp signal or a stop/yield sign, which would slow down the traffic stream. The video does not provide any other meaningful insights.

## US 67 South of Rock Island and North of Viola

| | |
|---|---|
| Started | March 1997 |
| Projected End | November 1998 |
| Date of Visit | July 9, 1998; August 3, 1998 |
| Work Description | Lane widening<br>Adding truck lane |
| Length of Workzone | 5 miles |
| ADT 1992 (ADT map) | 5,100 vehicles (10% trucks) |
| IDOT District | 2 |

## Workzone Description

The RE indicated that the project consisted of widening the traffic lanes to 12-feet and adding a truck lane. The construction work started at 7 a.m. and ended at 6 p.m. six days a week and was qualified by the RE as "moderately heavy" on a daily basis. No detour for the workzone was recommended for drivers, and many trucks use this route to avoid the weigh station in the area. The road is on a hillside and the sight distance issues present challenges to the selection of proper TCD.

## Layout and Traffic Control Plan (TCP)

On July 9, 1998, the five-mile workzone had lane closures at two different locations. Each closure was about half a mile long and controlled by two flaggers equipped with a SLOW/STOP paddle and communicating through a two-way radio. One flagger allows traffic to move after the last oncoming vehicle, as described by the other flagger, passes him. Regardless of the advanced warning signs about the lane closure and the traffic control, some drivers still did not see and immediately obey the flagger. Since that time, three orange cones have been placed in front of the flagger to help the drivers locate him when approaching the lane closure. Concrete barriers were considered as a means to separate the stopping vehicles from the flagger, but rejected because in the event of a collision, the concrete barrier might hit the flagger causing injuries.

This project had many of these sporadic closures, and the flaggers help to ease the entrance and exit of construction trucks in and out of work areas and the progress of temporary work on the shoulders. The RE said that arrow boards could have benefitted these closures, but they were not budgeted.

The contractor on this project has taken major safety measures. For example, he paid for the 45 mph flashing speed limit signs to warn drivers to slow down through the workzone. He installed signals with push buttons to provide access for private residences. The contractor also hired a safety inspector to regularly inspect the equipment condition such as the batteries of the TCD, their layout and others. Such measures are believed by the research team to have improved the safety of the contractor's workers as well as reducing his insurance costs.

The RE inspects the TCD every day. The supervising traffic engineer inspects weekly, and a traffic technician from Springfield inspects once a year.

## Crashes During Construction

Three crashes occurred at the beginning of the project. Although the RE had received copies of the reports from the Illinois State Police, he did not make them available for review. The first three reports, according to the RE, reflected problems with the TCP. It recommended the first warning sign to be placed at the top of the hill when the flagger was located at the bottom. Drivers were able to see the sign only when they had reached the top and did not have then enough distance to stop. One afternoon, a driver failed to notice the sign in time and rear-ended the vehicle stopped in front of the flagger. As a result, the flagger was hit and injured. The RE's solution was to move back the warning signs and add a second warning sign, close to the first one. One additional crash occurred during construction which was made available with the supplemental form attached. This crash involved a rear-end collision where vehicles were stopped for the flagger. The at-fault driver was cited for "speed to fast to avoid an accident," but the reporting officer on the supplemental report indicated the contributing cause to be distractions within the vehicle rather than speed.

## Summary of the Film Findings

This site was filmed at two locations during the second visit on August 3, 1998. The video shows a one-lane reduction using barricades and cones, the two flaggers (Pictures 2 and 3) and their equipment, the stopped traffic, and the construction work in progress.

The delay of the stopped vehicles at one end (Picture 3) is attributed to the time during which the opposing traffic is moving and the time during which the two flaggers do not allow any vehicle to proceed to make sure that all the vehicles in between have cleared the construction area. The video shows 20 dump trucks entering and leaving a work site (Pictures 4 and 5) located between the two flaggers during a 15-minute period of filming. Their driving can be characterized as rather aggressive and hazardous. On one occasion, a dump truck missed the entrance of the site and had to back up in the construction lane before pulling into the site. Moreover, the dump trucks do not cover the material they are carrying which might result in load spills, thus creating serious hazards to the following vehicles.

A big percentage of commercial trucks with fairly high speed going up and downhill were observed. Consequently, these trucks may not have enough distance if they have to suddenly stop. The video shows a "near miss" between two vehicles after the first one suddenly stopped to pull into the site. Had a commercial truck, which requires a longer stopping distance, been following that vehicle, a crash might have occurred.

The second part of the video taped the actions of one of the two flaggers (Picture 2). He reported having shifts that range from 10 to 12 hours. That is a long shift, which could lead to fatigue and potentially serious mistakes. For example, in the video, the two flaggers had a moment of confusion when the last vehicle was presumed to have gone into one of the driveways. After a while (for safety reasons) the traffic was allowed to proceed again. The flaggers do not count the number of vehicles going by, and only occasionally they report to the other flagger the license plate number of the last vehicle (Picture 6). In general, they try to describe a noticeable feature that characterizes the last vehicle. However, the failure to be positive about all vehicles clearing the site is a risk factor suggesting a need to improve the system.

Queue length is substantial during peak-hours; in one case about 20 vehicles were waiting at one end. The delayed drivers exhibited some frustration when they tried to overtake other vehicles after being allowed to proceed.

The video also shows workers crossing the road on foot frequently (Picture 7), which may put them at risk.

In conclusion, the video shows a rather heavily traveled work area during rush hour, heavy construction work, challenging terrain and a workzone that offers many distractions to the drivers.

**US 67 South of Viola and North of Alexis**

| | |
|---|---|
| Started | February, 1998 |
| Projected End | Not available |
| Date of Visit | July 9, 1998 |
| Work Description | Lane widening<br>Change of the lanes alignment |
| Length of Workzone | Not available |
| ADT (1995 ADT map) | 2,300 vehicles (15% trucks) |
| IDOT District | 2 |

## Workzone Description

The discussion with the RE was very brief because the workzone did not present a lot of interest to our project. It is located south of the workzone described in section 2 and controls a one-lane closure with traffic signals. The work activity is substantial and the traffic volume is very low.

## Crashes During Construction

Two crashes occurred at the beginning of the project. The RE did not have copies of the reports available but stated that because of challenging terrain, drivers could not see the traffic signals in time. They did not have enough distance to stop. Subsequently, the traffic signals were moved further upstream, giving the drivers enough time to see the signals and stop adequately. No further crashes occurred.

## Summary of the Film Findings

The traffic signals are indicated to drivers through static warning signs (Picture 8). An approaching vehicle triggers a detector, which causes the traffic signal to turn green. If vehicles are present on both sides, the green cycle lasts only for a limited time period and the traffic signal behaves like a pre-timed traffic signal (Picture 9). Detectors between the two traffic signals detect the last vehicle of one direction before the traffic from the opposing direction is allowed to proceed. In the video when this occurred, traffic from both directions was stopped. The only obvious potential problem as depicted by the video is drivers stopping beyond the traffic light (Picture 10). Consequently, they might have to back up, to avoid a head-on collision with the opposing traffic.

Compared to flaggers, the traffic signals best handle *short* and *permanent* one lane closure. For example, it is economically more efficient to use the signals when the one lane closure is in place 24 hours of the day and for a long period of time.

## I-80 East of Morris in Ottawa

| | |
|---|---|
| Started | March, 1997 |
| Projected End | October 1,1998 and December 15, 1998 |
| Date of Visit | July 8, 1998 |
| Work Description | Rehabilitation of IL 47 interchange<br>Replacement of two bridge decks on I-80 west of IL 47 |
| Length of Workzone | 3 miles (from milepost 109 to milepost 112) |
| ADT 1997 | 21,400 vehicles (33% trucks) |
| IDOT District | 3 |

## Workzone Description

The IL 47 interchange had new on- and off-ramps built to meet the new federal standards. The new westbound off-ramp was not open to traffic which was being handled by a temporary off-ramp and will not be open until the rehabilitation of the interchange is completed. At the time of our visit, the southbound lanes were being rehabilitated and the traffic was handled by a two-lane two-way operation (TLTWO) on the northbound lanes of IL 47. Work on the northbound lanes was scheduled to start once the southbound lanes were completed. The traffic on I-80 was handled by a TLTWO with a concrete barrier median on I-80 eastbound lanes.

The construction work started at 7 a.m. and ended at 5 p.m. six days a week and is qualified by the RE as "heavy" on a daily basis. He also stated that on certain days the work is so heavy that drivers slow down to observe some of the construction operations. He indicated that evening rush hours run from 4 p.m. to 6 p.m. with Mondays and Fridays being the worst days. However, he claims that in the absence of incidents or temporary road closures no queues are observed on I-80 or at the intersections near the interchange.

**Layout and Traffic Control Plan (TCP)**

The RE stated that he did not have problems with the TCP. Monthly, a traffic engineer hired by the contractor inspects the TCD's and layout. IDOT inspections are done weekly by a traffic engineer from the Ottawa District and daily by the RE.

Temporary actuated traffic lights have been placed inside the interchange, mainly at the level of the ramps. Microwave detectors are used to determine the splits (green time) based on the prevailing traffic conditions. The intersection on the south end of the interchange has actuated traffic lights with detectors in the pavement. The video captures this setup.

Traffic is first warned of the TLTWO on I-80 five miles upstream of the merge (in this case the closure of the left lane) and reminded every mile using diamond orange warning signs. In addition, about three miles upstream of the closure, in each direction, a VMS displays the same type of advance warning. The RE indicated that commuters, local drivers and truckers pay more attention to the VMS than to the static warning signs. In light of this fact, IDOT recommended that the RE frequently rephrase the message on the VMS to attract the drivers' attention. Finally, two consecutive electronic arrow boards located at about 1500 and 300 feet before the beginning of the taper warn drivers about the immediate merge. The taper starts under the interchange to quickly channelize the westbound traffic into one lane which merges traffic from the westbound on-ramp. The traffic is then gradually shifted to the TLTWO (see video for setup).

The RE mentioned that he has hired police officers with funds allocated by the 'hire back program." He stated that all of the available funds were used early on during the project.

The two VMS are rented every month from a subcontractor at a cost of $1000 per month. The concrete barrier has reflectors on the top and one foot yellow strip on the side. The concrete barrier median offers great resistance; however, at some locations the barriers had been moved out of their original positions probably as the result of being struck by trucks. Certainly its presence has avoided a head-on collision. Drums on the shoulder prevent people from using the shoulder as a traffic lane. However, as we were driving through the workzone, a driver five vehicles ahead of us stopped in the shoulder causing a sudden slow down. This might have caused a chain crash because there is no escape available for a vehicle traveling behind at a high speed.

Flaggers control the access of the construction trucks to the work area. In the case of an emergency, Route 52 (north of I-80) is the detour recommended.

## Crashes During Construction

The RE had on file only two minor (PDO) crashes resulting from driver's error, which occurred in March and June 1998. According to the RE, neither appeared to be related to the TCP or TCD's. The project team did not request copies of these reports because they were not caused by elements of the workzone. No further crashes were reported in this zone.

## Summary of the Film Findings

The first part of the video shot on July 8, 1998 shows the signalized intersection of the interchange. The traffic is directed into and out of the interchange by using plastic barriers and one arrow board (Picture 11). Despite the seemingly high volumes, the signalized intersection appears to be operating smoothly. For example, the left turning bay has sufficient capacity and the traffic signal's cycle length seems to be handling traffic appropriately.

The second part of the video shows that on I-80 westbound lanes the merge and the lane shift are being handled very effectively. For instance, although the traffic on I-80 meets with the westbound on-ramp traffic, the two lanes meet after all the traffic on I-80 has been channelized into one lane with a large width that creates perceptually comfortable and safe driving conditions (Picture 12). Unlike the project described in section 2, this setup minimizes the risk of a sideswipe, same-direction collision. The video shows a yield sign at the end of the on-ramp.

The off-ramp before the taper on I-80 (Picture 13) is certainly contributing to reduce the flow through the workzone, as many vehicles are seen exiting the Interstate. This creates larger gaps (Picture 14) and more space to merge, which helps to alleviate congestion inside the workzone. Furthermore, the drivers appear to follow the recommendations of the advanced warning signs as the video shows a large proportion of the traffic already in the appropriate lane.

The third location on the eastbound I-80 lanes (Picture 15) was shot on August 3, 1998. The video shows that the traffic is following the advance warning signs and very few late merges are observed. Trucks were found to contribute to late merging in two different ways. First, drivers behind a truck and still far from the taper almost always choose to overtake it to avoid driving behind it inside the workzone. However, if the vehicles are very close to the taper, in the majority of the cases they chose not to merge late in fear of not being able to merge on time. The rainy weather on that day could have been a contributing factor in discouraging the drivers to merge late.

**IL 120 in Gurnee**

| | |
|---|---|
| Started | October 1, 1998 |
| Projected End | November 30, 1998 |
| Date of Visit | October 20 , 1998 and October 27, 1998 |
| Work Description | Bridge deck repair |
| Length of Workzone | 0.2 miles |
| ADT (1992 ADT map) | 26,000 vehicles (5% trucks) |
| IDOT District | 1 |

## Workzone Description

Construction along IL 120 in Gurnee was at the bridge over the Des Plaines River with patching being done in one lane, in each direction. The roadway is a four-lane median separated both before and after the bridge. During construction each direction was reduced to one lane for a distance of approximately 200 feet prior to the construction zone. Both directions were clearly marked with construction ahead and lane closure signs. The speed limit on both approaches was 55 mph with 45 mph posted in the workzone. Construction lasted approximately two months.

On the eastbound approach, vehicles merged from IL 21. Merging was done after IL 120 had been reduced to one lane of travel. The merging ramp was marked with a yield sign.

Because of faulty recording equipment, traffic volumes, classification, and speeds in the vicinity of the workzone were not performed. Radar-based speed studies were conducted approximately 1200 feet east of the workzone for traffic traveling west and approximately 2400 feet west for eastbound traffic. Figure 6 shows the results of the studies. In both cases, the average speed was at the speed limit. For both directions, approximately 5 percent of all motorists exceeded the limit by 10 mph or more.

## Crashes During Construction

During the period, the Lake County Sheriff's Department responded to four vehicle crashes at the site. All involved minor property damage only with no injuries reported. Two of the crashes resulted from one vehicle striking another, which had slowed or stopped near or in the workzone. The other two were sideswipe collisions resulting from a vehicle entering from the on-ramp, striking a vehicle traveling in the one-lane portion prior to the work area. In only one case did the speed of the vehicles possibly play a role when one vehicle slowed suddenly to avoid a vehicle entering from the shoulder and was struck by a following vehicle.

What the crash reports suggest in regard to the sideswipe collisions is that merging entering vehicles into an already reduced number of lanes on a relatively high-speed roadway can create problems. While there is not a clear solution to the layout and Traffic Control plan as it existed for IL 120 (the merge was very close to the actual construction site), it does indicate that such merges should be avoided where possible.

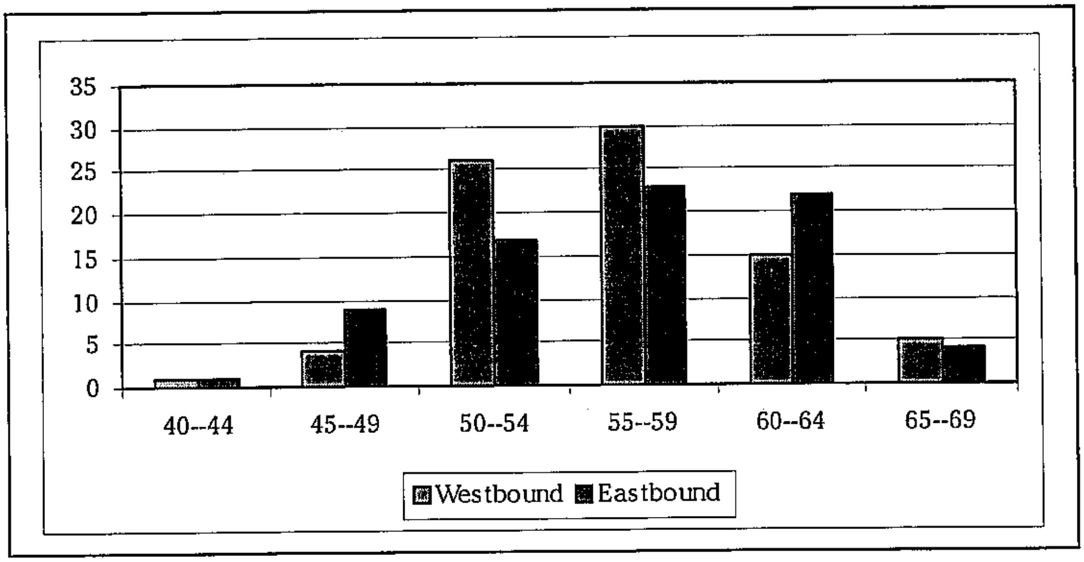



**Figure 6**
**Speed Distribution for the Westbound and Eastbound Traffic Approaching the Workzone**

## Summary of the Film Findings

The video shows merging under saturated traffic conditions. In the presence of a queue and therefore low speeds, a larger proportion of vehicles than at other sites chose to merge late, closer to the taper. As a result, most late merges bring the queued vehicles to a complete stop when they force the merge (Picture 16). On the other hand, some drivers in the queue accommodate the late mergers by creating gaps. As a result, the late merging vehicles never actually come to a full stop but rather move easily into the lane. In some instances, drivers exhibited vigilante behavior (Picture 17) by putting their vehicle in the middle of the two lanes and thus preventing the late merging vehicle from overtaking them (Picture 18).

### IL 68 (Dundee Rd) Across I-294, Northbrook

| | |
|---|---|
| Started | April 1999 |
| Projected End | November 1999 |
| Date of Visit | Multiple during 1999 |
| Work Description | Bridge replacement over I-294<br>Two-way traffic across the bridge |
| Length of Workzone | 0.8 miles[16] |
| ADT 1995 | 30,000 vehicles (3% trucks) |
| IDOT District | 1 |

16 Although the portion of two-way traffic was approximately 0.2 miles long, because of the roadway geometrics, the entire workzone stretched approximately 0.8 miles with most of that distance being single-lane traffic westbound.

## Workzone Description

Construction is limited to replacing the bridge across the Tri-State Tollway (I-294) just west of Sanders Road on Dundee Road (IL 68). Work is done in two phases with the north lanes replaced first and traffic reduced to one lane in each direction over the eastbound lanes on Dundee. That work was completed in July and traffic switched to the new lanes across the north side of the bridge. All construction is separated from traffic by the use of temporary "Jersey" type concrete barriers.

Dundee Road is a 4-lane, undivided arterial street. Vehicles traveling west pass through Northbrook with a speed limit of 45 mph. Approximate 0.5 miles from the bridge is the intersection with Sanders Road a minor, two-lane, north-south, arterial. Right and left turn lanes are provided at Sanders from both directions of Dundee Road and left-turning traffic has a protected phase.

Traffic traveling eastbound passes through an unincorporated area and a forest preserve just east of Wheeling (although Wheeling police handled any crashes occurring at the west side of the construction). Speed limit is 50 mph, and there is one intersecting street, Portwine Road, approximately 0.8 miles from the overpass. Most traffic using Portwine is coming from the west and turning left into that street.

The taper westbound begins prior to Sanders Road, narrowing to one lane, but providing both the right and left turn lanes at the signal. The road had one lane on the other side of the traffic signal until past the bridge. This configuration has remained the same throughout the project.

Eastbound, the taper and single lane began approximately 400 yards from the start of construction. The same configuration has remained even though traffic has been shifted. The RE specifically requested this form of traffic control because it would provide consistent control throughout the zone.

## Crashes During Construction

Only four crashes using the supplemental forms were reported by the Northbrook Police. A review of the crash reports shows that for three (one was a desk report without an Illinois PCR being completed), the problems occurred outside the actual working area and resulted from improper driving. Two were rear-end collisions at low speeds, and the third was a sideswipe. While there were traffic control devices in place at or near the sites of the three crashes, none of the crashes can be related to a specific control.

## Summary of the Film Findings

Filming was done showing both approaches and traffic merging into the single lane eastbound during the peak morning period. Most vehicles merged smoothly with an occasional display of vigilante behavior. Traffic was so heavy in the morning that queues as far back as Portwine (up to 0.5 miles) are possible. Most drivers at that period are regular commuters and appeared to have learned how to handle the merge. Most waited until the taper to begin their merge. Observations off peak showed that merging does occur earlier.

No filming of westbound traffic was done. However, the merging and traffic behavior is complicated by the turns being made at Sanders and the fact that when traffic is stopped on Dundee Rd, southbound Sanders is providing heavy right turning (westbound) traffic into the site. Any delays westbound at the site then affect the queue on Dundee causing additional delays.

## Recommendations for Improvements from Onsite Observations

This section formulates recommendations based on the video observations and the discussions with the resident engineers. A measure of their effectiveness is not presented in this report because the proposed solutions have not been tested in the field. The authors believe that the resident engineers have addressed the problems properly, but that these solutions have never been documented *and* used at other sites before the work actually started. Therefore, the effectiveness of the solutions is based on the reported improvements at the sites described in this report and this section introduces a formulation for their systematic use at future workzones.

### Traffic Control Plan Review

- The plan should include the TCP standards, but then have the RE in charge evaluate it based on his experience and judgment. Furthermore, a review committee consisting of the RE and the supervising traffic engineer should be formed to investigate potential problems as soon as the work starts.

The initial TCP and layout recommendations have been altered significantly at most of the sites visited. The fact that many of the crashes occurred when the workzone opened suggests that the standards used to develop the TCP might not have accomplished their objectives. On US 67, the initial location of the warning signs and of the traffic signals as recommended by the TCP led to a total of five crashes when the work started. On the other hand, delegating to the RE the responsibility of *designing* the TCP is certainly not the answer to this problem. On I-74, the constrained driving conditions led drivers to encroach on the soft shoulder, which led to most of the crashes.

- IDOT could require the contractor to hire a TCD safety inspector for more frequent and safer inspections.

Currently, the RE inspects the workzone and the TCD on a daily basis while the supervising traffic engineer inspects it on a monthly basis. Based on the encouraging results of US 67, the cost of hiring the safety inspector would be outweighed by the cost of a crash resulting from a defective TCD.

- The review committee should start their investigation of crashes immediately after the first occurrence to identify the contributing factors and make the necessary changes.

Crashes occur mainly because of driver error, but contributors are limited sight distances such as in hilly terrain, type of work being performed at the time of the crash, the type of TCD used or not used, and the layout of the TCP. The problem with the soft shoulder on I-74 was addressed after a month of operation and several crashes. This immediate and reactive investigative effort helps identify the problem early during the life of the workzone and thus potentially reducing the number of crashes.

- To assist the review committee during the process, a supplemental police report, such as the one developed in this study, should be used to investigate all the workzone crashes.

The police officer present at the crash scene would complete the supplemental report and distribute the report to the police district and the review committee. This should help to identify the problem and formulate appropriate measures. The necessary analysis skills can be taught to the review committee with a short course or a debriefing at the respective districts.

- The solutions the review committees employ at various workzones can be used to review the TCP standards.

In essence, the role of the review committee is not limited to solely providing solutions but also to report these solutions to the IDOT for review of the TCP standards. As a result, a set of problems and solutions are available to traffic engineers during future TCP design and for researchers to evaluate and improve them.

**Monitoring and Evaluating Workzone Operations**

- Use a video camera to monitor the workzones.

The videotaping of the workzones and the analysis of the crashes show that a continuous monitoring of the workzone helps the review committee to assess faster and more accurately the contributing factors. Use of video cameras for monitoring the workzone at different locations can be a valuable tool to evaluate the overall safety of the workzone. Additionally, the videos are evidence to be used by the review committee when determining the cause of a crash. As a result, any uncertainty associated with the police crash reporting is reduced. Video monitoring can also detect the driving behavior and warrant appropriate measures before crashes happen. It also assesses workers safety and their behavior. For example, on US 67 the workers were observed to cross the road frequently, putting themselves and the drivers at risk of a crash.

- Use speed-sensing devices not only to trigger flashing signs, recommending to drivers violating the speed limit to slow down when appropriate, but also to collect speed data.

While traffic engineers considered speeding a problem in workzones, it is not clear when the problems arise or whether the speed limit is appropriate for the traffic and workzone conditions. One use of the speed monitoring data is to establish the best times to use off-duty police for speed enforcement as well as identifying locations prior to or inside the workzone where excessive speeds may lead to crashes. Furthermore, a causal relationship between a type of TCD and the observed speeds or speed differentials can be observed. For example, speed differentials can be measured following the posting of a speed limit sign.

## Police "Hire-Back Program"

- Consequently, IDOT could require the contractors to include in their bids an itemized cost for hiring off-duty police officers at workzones, but also to have specified patrol and enforcement duties.

The resident engineers at most sites (where applicable) reported hiring off-duty police officers using the money allocated by the "hire back program." The presence of police officers with flashing lights has been shown to be effective in slowing down the traffic. However, they all said that the money allocated is insufficient and was consumed after a few months of operation. Moreover, the police usually patrol inside the working area controlling speeds and spend a limited amount of time prior to the actual construction area. Police officers should be present on days of intense work activity, congestion, or specific type of lane closures with attention paid to drivers entering the working area rather than speeds within the area itself. For example, their presence might discourage late mergers. Within the area, they should be enforcing following distances, and outside the construction area, speeds and merging behavior. Fines collected from the citations issued could be returned to the Road Fund in this case rather than the local jurisdiction. This would offset the costs of hiring the officers.

The hiring of the police officers must plan for the number of police officers required, an observation location that contributes at least to crash risks and sufficient curb space to pull over the violators. The experience of the police officers and their recommendations can be used as input in the design of the workzone.

Clearly, the effectiveness of hiring off-duty police officers needs to be further investigated. It seems, however, that the resident engineers like this control measure and assume that if not scientifically at least empirically it works.

- An alternative recommendation is to have dummies inside police cars.

Without frequent alternation between dummies and live enforcement, the drivers quickly become accustomed to, and ignore, the vehicles with dummies.

## Advance Warning Signs

A large body of research is available on the type of warning signs to use at workzones. This section reports some of the types of warning devices that are popular with resident engineers and drivers.

- Use VMS and changeable messages to capture drivers' attention and trust.

It is important to develop a trustworthy relationship between the drivers and the warning devices. For example, if work is in progress but speed reduction is not necessary, the warning sign should not demand the speed reduction. To do otherwise will impact the drivers' compliance rate in the future. Advance warning signs such as the ones used on the I-80 project warn the drivers every mile of the merge. As the drivers approached the workzone, VMS replaced the static warning signs. The displayed message on the VMS is updated on a real-time basis based on the work activity. Truckers pay most attention to the VMS messages because they feel that the real time nature of the message and its recommendation are in accordance with the work activity inside the workzone. VMS are reported to be more effective and reliable with drivers than static signs. The disseminated messages can be updated continuously from a remote location using a cellular phone. Such success probably explains the low number of crashes since the beginning of the project on I-80.

- Use real-time and visually stimulating warning devices such as warning signs with flashing lights across the road, arrow boards should be used more frequently.

For example, the approach to the flagger on US 67 would probably have benefitted from an arrow board but the necessary budget was not provided.

- To stimulate the driver's understanding and compliance, video screens could be located upstream of the workzone giving drivers a look ahead on the workzone.

Presented with visual evidence, the drivers might pay better attention to the sign's recommendation. Such a device also would show when queues are forming which otherwise might be unexpected.

- Use optical warning signs to provide recommendations to be read only by drivers of one particular lane.

For example, drivers in the passing lane can be encouraged to merge earlier through one optical sign while a second optical sign might ask drivers of the merged lane to create gaps so they can accommodate the merging traffic. A phenomenon was observed on IL 120, where vehicles in the merged lane were creating gaps to accommodate the merging traffic.

**Flaggers**

- Use flaggers in the area of the actual work when it is hidden from flaggers at either entrance to the construction zone.

On the US 67 site north of Viola, flaggers were the appropriate traffic control for that type of lane closure. However, in the presence of driveways in between the two flaggers, a system leakage can and was observed. System leakage occurs when vehicles enter or leave the stream of traffic somewhere inside the lane closure. At US 67, a third flagger should have been located at the entrance of the construction site to control the access of the dump trucks into and out of the site.

- For their safety, the flaggers should be raised above the ground level to increase their visibility from afar.

In addition, a barrier can be placed between them and the driving lanes to help protect from errant drivers.

- In rural areas, use temporary traffic signals as substitute for the flagger.

At the one US 67 site, the temporary traffic lights were used at the driveways to monitor the traffic access especially at night where the presence of a flagger is not realistic. On US 67 north of Alexis, the traffic lights were appropriate because the opposing traffic could see each other and because the volume is very low and the cost of the flagger cannot be justified.

**IMPORTANT FINDINGS**

1. Resident Engineers appear very knowledgeable regarding the situations that affect traffic flow in a specific workzone and take the initiative to account for the situations. While workzone traffic controls are established according to standards, greater flexibility regarding their implementation may be warranted, especially based on the local knowledge of the RE.
2. Police crash reports for crashes occurring at the start of the construction have been used by RE's to re-examine the role of the TCP and TCD's in collisions. They have provided a basis for the RE to take corrective action.
3. Changes made by the RE's are not formally published so that they might be of value at other sites; they should be.
4. The videotapes suggest that drivers often do not abide by the warning signs and take action, especially merging, only when the action is required.
5. Merging appears to generate conditions which can contribute to crashes. This was supported by observations of driver behavior from the videotapes (see Chapter 8).
6. On two-lane rural roadways where the flaggers cannot see each other or the entire roadway, they can fail to identify the last vehicle passing their location. This can cause unnecessary delays while the other flagger waits to make sure the roadway is clear. They also are not aware of activity on the roadway which would create a danger to motorists or workers.

## 8. Speeds and Driver Behavioral Classification

Speed studies and videotaping were used to understand the relationship between the design and activity at a construction zone, speed of vehicles, and the drivers' behavior. The supplemental reporting for crashes showed that the speed of vehicles as they approached the taper was important. None of the supplemental reports reviewed, or the narratives accompanying those reports indicated that speeds within the workzone were critical in relationship to the workers or activity, only as those speeds related to the degree of congestion. Indeed, the only worker injured was a person who improperly backed her pickup truck, lost control, and ran into a vehicle in the travel lanes. In this one case, the improper action on the part of the worker, not the passing motorist, was clearly the contributing cause; yet also in this case, no citation was issued.

Driver behavior at the approach and taper also was important because most maneuvers required of a driver in a workzone occur at this point. Here, the typical crash is a sideswipe or rear-end, but unlike inside the working area, such a crash also is more likely to result in injuries. This analysis is valuable because it shows that although the warning recommendations used were descriptive and prescriptive, that is their message described to the drivers the conditions ahead and formulated adequate safety measures, they were not preventive, that is, not all drivers complied with the recommendations. Indeed, some drivers ignored the recommendations of the warning signs, a situation which might have led to a serious outcome. The second section categorizes the drivers' behavior and recommends preventive measures.

### Vehicle Speeds

Speed studies were conducted at three locations. Extended attempts to obtain working traffic analysis equipment (including speed measurements) precluded the use at more sites, especially in 1998. Speed and volume readings were obtained in 1999 at I-80 in Joliet, and IL 68 (Dundee Road) in Northbrook. Table 43 displays a summary of the speeds and volumes. Speeds for I-80 come from the lane that merges. For IL 78 (see Chapter 7 for discussions of details about the site), the speeds come from the through lane. Speed distributions based on radar readings for IL 120 appeared in the discussion of this site in Chapter 7.

**Table 43**
**Hourly Average Speeds and Volumes on the Approaches to Workzones**

| I-80 | | | Dundee Rd (IL 68) | | |
|---|---|---|---|---|---|
| Time | Hourly Volume | Average Speed | Time | Hourly Volume | Average Speed |
| 11* | 103 | 41.6 | 5 | 38 | 45.6 |
| 12 | 95 | 56.7 | 6 | 170 | 41.8 |
| 13 | 227 | 32.0 | 7 | 910 | 19.4 |
| 14 | 141 | 30.1 | 8 | 731 | 23.5 |
| 15 | 210 | 25.5 | 9 | 203 | 44.0 |
| 16 | 437 | 26.5 | 10 | 168 | 44.6 |
| 17 | 162 | 47.7 | 11 | 168 | 41.9 |
| 18 | 173 | 54.2 | 12 | 173 | 44.0 |
| 19 | 212 | 58.0 | 13 | 177 | 43.9 |
| 20 | 170 | 49.6 | 14 | 156 | 44.2 |
| 21 | 82 | 57.6 | 15 | 166 | 43.2 |
| 22 | 90 | 52.4 | 16 | 136 | 45.4 |
| 23 | 51 | 55.7 | 17 | 205 | 44.9 |
| 24 | 41 | 57.2 | 18 | 146 | 46.7 |
| 1 | 25 | 54.1 | 19 | 105 | 44.2 |
| 2 | 22 | 61.3 | 20 | 90 | 44.8 |
| 3 | 15 | 50.4 | 21 | 57 | 41.4 |
| 4 | 44 | 58.0 | 22 | 22 | 44.4 |
| 5 | 121 | 57.1 | 23 | 21 | 42.7 |
| 6 | 217 | 58.4 | 24 | 1 | 40.0 |
| 7 | 185 | 51.2 | 1 | 6 | 41.5 |
| 8 | 271 | 56.0 | 2 | 1 | 41.0 |
| 9 | 149 | 50.6 | 3 | 2 | 40.0 |
| 10 | 100 | 42.8 | 4 | 6 | 47.7 |
| 11 | 67 | 37.4 | 5 | 40 | 46.8 |
| 12 | 118 | 41.2 | 6 | 226 | 45.5 |
| 13 | 258 | 29.9 | 7 | 971 | 24.1 |
| 14 | 169 | 25.8 | 8 | 682 | 26.2 |
| 15 | 205 | 26.7 | 9 | 188 | 44.5 |
| Total (30 hrs) | 3384 | 44.6 | | 3913 | 36.2 |
| 24-Hour Avg | 2707 | | | 3130 | |
| 13-15 hrs | 605 | 28.4 | 07-09 | 1843 | 25.4 |
| Other hrs | 2102 | 58.0 | Other hrs | 1287 | 107.9 |

* 1100-1159

## I-80 Near Joliet

Approach speeds on I-80 generally exceeded the workzone limit of 45 mph (an average of 52.6 mph during the off-peak hours) except during periods when obvious queuing was taking place in the through lane; therefore traffic in the merging lane also was forced to slow. At these hours, the average speed was 28.4 mph. This can be seen in Figure 7 for the period from 1300 until 1500 on the two days covered by the study (June 9 and 10). However, the overall average of 44.6 mph is below that posted prior to the workzone, 65 mph. What is interesting about this graph is that the merging speeds never fall significantly. Although the through lane volumes were not available, the plot in Figure 7 shows that merging volumes in one case exceeded 400 vehicles per hour (a total of 1700 on day one). Even with the 15-minute counts that were used, at no point did the average speed over the 15-minute period fall below 20 mph.

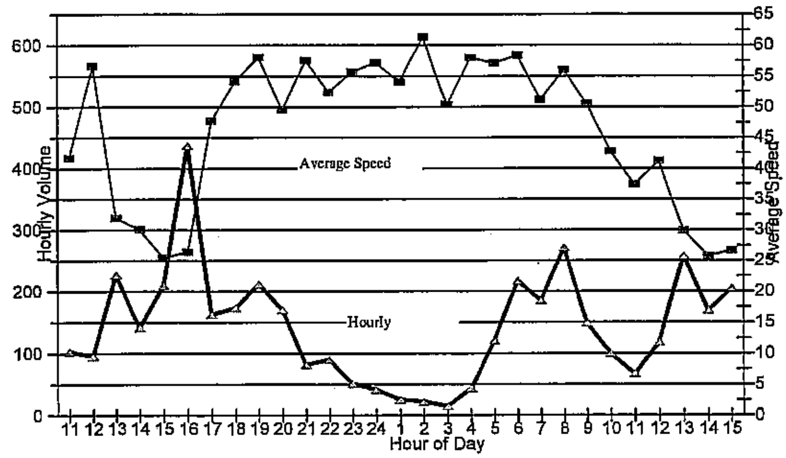



**Figure 7**
**Speed/Volume Summary**
**I-80 Merging Lane**

Given the location of the detector, and assuming a volume of 1400 vehicles per hour at the end of the taper (based on an average speed of 25 mph which is the same as for the merging traffic), suggests that approximately 15% of the merging vehicles did so either within 100 meters of the start of the taper or within the taper itself.

## IL 68 (Dundee Road) at the Tri-State Tollway

At off-peak hours on IL 68, the vehicle counts should be representative of the actual hourly volumes because the video showed that drivers merged far in advance of the taper and the detectors were located only 100 meters from that start. During the peak hour, the volume also must include merging vehicles. From observing the video taken on IL 68, at least 20% and probably closer to 30% of the through traffic came from merging drivers. This yields a throughput at the taper of 1400 vehicles per hour, approximately the same as estimated for I-80.

On IL 68, the peak lasted two hours eastbound. It averaged approximately 800 vehicles per hour. Speeds, as shown in Figure 8 decreased on one day to approximately 20 mph, and on the other to 25 mph. During the off-peak hours, the average approach speeds ranged between 40 and 45 mph. This range is below the 50 mph speed limit marked on IL 68 and suggested that motorists were taking into account the change in driving configuration and adjusting the speeds accordingly. Unlike I-80, many of the motorists on IL 68 represent regular travelers who might drive the roadway several times daily and at a minimum twice a day for commuting. As was the case for I-80, the speeds, even during queuing generally were in excess of 20 mph which meant that most drivers did not experience excessive delay. Had queues been longer, delays also would have increased. This reduction in speed also might explain the absence of crashes along the construction zone as described in Chapter 7.

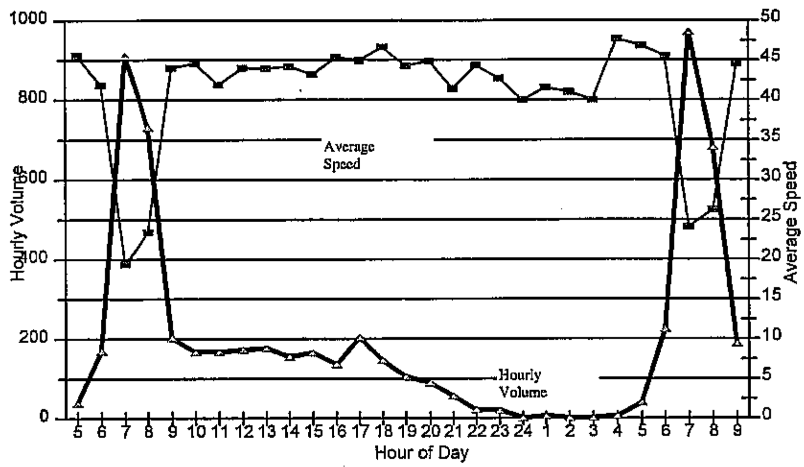



**Figure 8**
**Speed/Volume Summary**
**IL 68 - Through Lane**

Except for the two peak hours, volumes also were quite low. They averaged less than 200 vehicles per hour with only minimal peaking during the evening commute period. These low volumes also meant that only occasional queuing would have occurred, and such queuing would have meant only a minimum slowing.

### Driver Behaviors

In addition to videotaping of approach behavior done along IL 120 (as described in Chapter 7), additional taping was done at a merge on I-94 (Edens Spur, Illinois Tollway) just west of the toll booth in Northbrook, and at Dundee Road also in Northbrook. From the videotaping, researchers established and measured several classes of driver behavior both in the merging and through lanes.

Table 44 lists for some of the videotaped sites the percent a given behavior was observed. The behaviors were classified as those from drivers of merging vehicles and those in the through lane. Specifically, five separate classifications were employed for the merging drivers:

- early merge (at a point early enough that no apparent slowing of traffic occurred)
- mid merge (into the queue of the through lane, but not near the taper)
- late (immediately before or into the taper)
- forcing (more than one driver attempting to enter the same gap in the through lane)
- using shoulder (moving to the shoulder to pass others and then merge at a later point)

Those in the through lanes were given three classifications:

- Vigilante (the driver who does not allow merging vehicle to move to the head of the queue)
- failure to yield (failing to provide a gap for the merging vehicle)
- stopping in lane (stopping to allow one or more drivers to merge)

**Table 44**
**Driver Behavior Classification**

| Behavior Type | IL 120 – 1st Visit | IL 120 – 2nd Visit | Interstate 94 | Dundee Rd IL 68 |
|---|---|---|---|---|
| **Merging Vehicles** | | | | |
| Early | 48.7% | 55.6% | 53.7% | 17.1% |
| Mid Merge | 41.7% | 29.0% | 5.8% | 12.2% |
| Late Merge | 9.2% | 14.5% | 40.3% | 65.8% |
| Forcing Merge | 0.4% | 0.9% | 0.2% | 4.9% |
| Using Shoulder | 0.0% | 0.0% | 0.0% | 0.0% |
| Est. Merging Volume (%) | 19.9% | 16.5% | 47.8% | 30.3% |
| **Through Lane** | | | | |
| Vigilante | 0.6% | 2.9% | 2.7% | 1.8% |
| Failure to Yield | 1.2% | 0.0% | 6.4% | 3.3% |
| Stopping in Lane | 0.0% | 0.0% | 0.0% | 0.3% |
| Rapid Approach to the Merge | 0.9%* | 4.8%* | 4.9%* | 0.3%* |
| **Flow (vph)** | 1,300 | 1,300 | 1,800 | 1,800 |
| * Percent of all vehicles approaching merge | | | | |

Finally, one behavior applied equally to both the through and merging lanes. This was the driver who approached the end of the queue at an apparent high rate of speed. It more often was noted in the merging lane.

## Merging Traffic

Early merging. An early merge was defined as a driver entering the traffic stream in the free flowing portion, or where a queue had formed, entering the stream prior to the queue. Such merging generally occurs without any noticeable interruption of the traffic flow. Under these conditions where no queue exists (or at the minimum, one consisting of two or three vehicles in the through lane), most drivers have been observed to merge early. These drivers are abiding by directions from the traffic control devices. In the videotaping, upwards of 50% of all drivers merged early, even though queues were present in all cases. However, as the traffic volume increased (and queues lengthened), the percent decreases, especially on the four-lane arterial roadway, IL 68.

Mid merge. The term "mid merge"was given to those drivers who tended to wait before merging, but who did so prior to the start of the taper. They had completed their merge by the beginning of the taper. However, their merge was made at very low speeds and into a gap that opened for them in the through lane. This type of merging behavior causes interruptions to the traffic flow, but normally only to the through lanes. The driver in the merging lanes rarely comes to a complete halt. This percentage decreased as the volume (and queuing) increased. Together with those who merged earlier in the stream, they constitute a majority of the merging traffic. One exception was on the lower speed arterial roadway (IL 68) under saturated conditions where most drivers merged at the last possible moment.

Late merge. The late mergers are not following the advance warning signs. This is the driver who may complete the merge as late as the transition from the taper to the construction area delineation. Often, the driver appears to be making a gap and then entering. Under saturated conditions, these drivers experience shorter travel times if they do not have to stop before they merge. However, when motorists in the through lane fail to create a gap it causes the merging vehicles to stop. The impact on the system can be added delays along with additional rear-end and sideswipe-same direction crashes. On the other hand, if the merge proceeds with each lane alternately providing a gap, traffic did not appear significantly delayed (but without modeling the behavior, the difference in delay for all drivers between a late and early merge could not be determined).

The film shows more late merging on the Interstate roadway than on the lower volume, limited access arterial roadway. It also shows that under lower speed conditions such as found on IL 68 (40 mph construction zone and a 50 mph approach), the late merging occurred frequently under congested conditions.

The higher volumes probably are more likely to encourage use of the available capacity near the merge because the drivers might believe that the geometrical characteristics on such a road allow them to negotiate the late merge easier and safer than it would be on other types of roadways. Late merging could be prevented using physical obstructions such as concrete barriers. Such measures, however, can migrate the problem further upstream or increase the number of vehicle collisions with objects.

Late merging probably cannot be eliminated (the perceived benefits are too high), but rather reduced with the use of one of two schemes. The first is the "Indiana merge." Instead of the signs which flash and state "45 mph When Flashing," the signs have been modified to state "Do Not Pass When Flashing." Up to five are placed at intervals upstream from the merge, and as detectors sense a queue building at the sign closest to the current merging location, then the next upstream sign is activated. Police enforce the "Do Not Pass" sign.

A more important aspect of this behavior is that if a driver merges earlier, and there is an extensive queue, some other driver will proceed to the head of the merging lane. That driver gains an advantage (especially as seen by others), but more importantly, that second merger now creates a situation where more than one vehicle merges for each through vehicle (in effect, reducing the amount of alternate feed). The delay to the through lane then becomes longer. Thus, instead of alternate feed, which can be done at low speeds with a smooth traffic flow, these multiple merges create perturbations in both streams and probably create even longer delays overall. A second suggestion then is to provide some form of lane divider in the last 500 feet and then ramp-control signals at the end which are sequenced to provide alternate merging. The driver now has the option of merging early or waiting until the end as before.

Forcing merge. This behavior occurs when two vehicles in the merging lane attempt to enter the same gap opened in the through lane. The second driver is forcing an opening rather than waiting for the next gap (or alternate merge). When this behavior was observed on film, both the merging lanes and the through lanes come to a halt. This has a significant effect on delay.

Using shoulders. The driver who was viewed using the shoulder had approached the end of the queue at a high speed and ended up on the shoulder to avoid a crash. Once there, however, the driver continued to the head of the merging queue before reentering the traffic stream (in effect, creating a 3 to 1-lane merge. Drivers also have been seen avoiding the merging queue by pulling onto the shoulder and using it as a travel lane. This behavior happens very infrequently, but can cause significant disruptions to both lanes along with creating a danger to any motorist who decides to pull off to the shoulder. Placing cones or barrels along the shoulder, especially near the head of the merge would help eliminate this behavior where it is observed.

**Through Traffic**

Vigilante behavior. The vigilante drivers cooperate with the warning signs and drive in the through lane, but out of frustration or "civic duty," place their vehicles in the middle of the two lanes to prevent any vehicle in the merging lane from overtaking them. Most frequently, drivers of semi-trailers undertake this action. In all likelihood, this behavior stems from lack of earlier merging and a mistaken impression that a vehicle proceeding to the taper to merge will create additional delays or somehow is "illegal". However, these motorists are violating traffic law. Moreover, their actions can be frustrating to others, and may lead to aggressive driving including passing on the shoulder. The irritation and unsafe behavior, in turn, may to crashes inside or at the end of the workzone. The videotapes captured numerous instances of the vigilante.

Such behavior might happen less frequently if smooth merging were occurring and both lanes of traffic moving at a continuous speed (especially if the merging is occurring away from the taper).

However, vigilante behavior is a violation of several traffic laws, and given that it has a potential to aggravate other drivers, needs to be controlled through education and enforcement.

Failure to yield. Failure to yield to merging traffic exhibits aggressive behaviors which also have negative effects on the traffic movement. As seen in the videos, as long as the merge is continuous, even with drivers merging at the taper, traffic tends to flow smoothly. When a driver fails to yield, the result is the same as a driver who attempts to force a merge into a gap already filled by a merging vehicle. Stoppage is created, especially in the through lane, and is for a longer period than what would have occurred had each driver shared the merging.

The recommendation for merging through the use of ramp control signaling might, in some part, reduce the problem. However, it is entirely possible that the driver who now fails to yield also will fail to follow the signal. Nonetheless, use of such signals would assist with enforcement; whereas, under current state law there is a limited ability of the police to handle this driver other than citing the driver for "impeding traffic flow," and thereby causing the aggressive driver to lose time as a result of his or her aggression.

Rapid approach to end of queue and to the merge. Drivers who rapidly approach the end of the queue are disregarding early cautionary signs regarding construction and potential changes in lane configuration. They may be unaware of the exact location of the end of the queue because of sight distance limitations. Members of the project team have witnessed behavior where a driver approached quickly and was forced to brake quickly or even use the shoulder to avoid a crash. The high speed can lead to serious crashes. Fortunately, as was shown in Table 44 these extreme behaviors requiring evasive actions were observed rarely.

One specific area filmed was on the Eden's Spur beyond the toll booths. When an open lane was available up to a merging point, some drivers were observed proceeding at speeds well in excess of the other traffic. Had another driver pulled out from the slowed lane to take advantage of the open lane, a collision easily could have occurred. Providing the drivers with visual information on the conditions ahead might encourage them to follow the recommendations of the warning signs. One method is to provide large screen displays to traffic conditions in the merging area, especially if that merging area is blind to the approaching driver.

Also, enhanced enforcement of speeds in the approach could be beneficial, especially if coupled with the use of variable speed limit signs. The latter are being used widely in Europe for congested conditions, especially on limited-access roads. Merging under high traffic volumes creates significant congestion and could easily warrant reduced speeds.

### Conclusions from the Videotaping

The videotape captures the drivers' behavioral randomness under different types of merging conditions and traffic control devices. It shows that some drivers rely more on their judgment rather than on the recommendations from the TCD, while the majority of drivers comply with the recommendations. The outcomes suggest that more attention needs to be paid to the traffic control devices, their messages, how they are placed, and how they operate. The experiment with the "Indiana merge" is one example. Additionally, enforcement may also play a role, especially if (1) the behavior occurs frequently, and (2) the crash rate could be reduced where the contributions are not external factors.

**IMPORTANT FINDINGS**

1. Speeds of vehicles approaching the merging area (the taper) on one Interstate highway (I-80) and the divided state highway (IL 120, non-limited access) were approximately equal to the speed limit. On the other hand, speeds lower than the limit were observed on the roadway (IL 68, non-limited access).
2. Approximately 20% of the merging vehicles do so in the last 100 meters of travel. However, when no queues exist, most drivers move to the through lane (merge early) well before the merge is required.
3. A number of merging behaviors, failure to yield to merging vehicles, excessive approach speed, and vigilante actions, observed create hazardous situations.

# 9. Recommendations for Workzone Traffic Control

## Recommendations

The report has addressed many aspects of the workzone which have created issues that can be resolved. This chapter addresses recommendations for action. The recommendations are divided into the following categories:

- Workzone planning including layout and operation
- Crash reporting and use
- Information to motorists
- Working area
- Approach and taper (especially merging lanes)

Within each category are actions. The actions are prefaced by a brief description of the problem and the basis for the recommendation. Potential costs also are addressed. However, most of the costs are negligible because the recommendations use the current practice, often placing emphasis differently. Table 45 summarizes the recommendations.

## I. Workzone Planning and Operations

### A. Use Resident Engineer (RE) experience in designing the workzone layout.

1. Problem:
   The layout, traffic control plan (TCP) and placement of traffic control devices (TCD), which are based on the Manual of Uniform Traffic Control Devices (MUTCD), may not take into account local variations or experience of the RE.

2. Basis for action:
   Traffic control plans observed in use at selected sites often had been altered as the result of field experience.

3. Action:
   The layout and plans should be reviewed comprehensively, on site before they are completed. This might eliminate some of the problems which have arisen, such as "Flagger Ahead" signs not adequately located. Changes can be anticipated by an on-site review of the plan before it is implemented. This suggests the merits of IDOT engineers in inspecting the entire area, examining it as it will appear from the perspective of the plan, and involving the assigned RE with its review prior to implementation.

**Table 45**
**Summary of Recommendations**

| Setting/Action | Data Source | Possible Costs |
|---|---|---|
| **I. Workzone Design and Operation** | | |
| Use RE experience in designing layout | On-site visits | N[1] |
| Record all changes in TCP or placement of TCD's on layout | On-site visits, review of plans | N |
| Regular inspection of the workzone TCD's | On-site visits | $100 to $200/week |
| **II. Crash Reporting** | | |
| Clearly marked workzone | Crash reporting; On-site visits | $400-$1,000 per zone |
| Modify crash report to meet MMUCC | Crash reporting | N (included with next PCR design) |
| Sharing data with RE | Crash reporting; On-site visits | N |
| **III. Educating Motorists and Better Information** | | |
| Use VMS to note when queues present or other unexpected changes | Videotaping | $20,000 to $40,000 per sign; $1,000/day rental |
| **IV. Working Area** | | |
| Use "Jersey" type concrete barriers to separate traffic from workers | Crash reporting | $1,000 per 100 feet; $500 to $1,000 per change |
| Provide escape areas when barriers used | Crash reporting | $500 to $1,000 per change |
| Shield activity from view by motorist | Crash reporting | $2,000 - $10,000 per unit |
| Reduce length of lane blockage | Crash reporting; On-site visits | N (possible savings) |
| Use variable speed limits (VSL) for changing working area speed | Crash reporting; Literature | (under study by NCHRP) $20,000 per sign |
| **V. Approach and Taper** | | |
| Keep lane shift and reduction consistent; use dynamic (Indiana) merge | On-site visits | N; additional signing $4,000 per sign |
| Maintain wider than normal lane after reduction | Crash reporting | N |
| Reduce one lane at a time | Videotaping | $1,000 to $2,000 for additional barricades |
| Use VSL to reduce speeds in approach when queuing present | Crash reporting; Videotaping | (under study by NCHRP); portable VMS, $20,000 per sign |
| Require alternate merge | Crash reporting; Literature | $4,000 per sign |
| Move enforcement to approach and taper | Crash reporting | N |

[1] N - negligible cost or cost already incurred as part of workzone operation.

4. Potential costs:
   Potential costs are negligible (some additional time taken by the RE to help with the planning and some additional travel). Development of the TCP already is a required task.

**B. Record all changes in layout, the TCP, and placement of TCD's on the construction plans.**

1. Problem:
   After the project is finished, data about changes that may be needed to review crashes or other events may not be available with the plans.

2. Basis for action:
   Because most construction plans do not carry a history of all changes to the TCP and TCD location, attempts to link crashes with the plans at a later date were not practical.

3. Action:
   As changes are made to TCD's or to the traffic control plan, the RE records the change on the original construction plans, either in its entirety or as a reference to a changes document which is maintained with the original plan. Not only would such history be beneficial to a subsequent study, but will allow the IDOT personnel an opportunity to study how plans change and to recommend changes to current standards. Without these data, analysis would have to be done using all RE records, assuming that *all* changes are recorded, for each site.

4. Potential costs:
   Negligible.

**C. An outside source should conduct a regular inspection of the layout.**

1. Problem:
   RE daily inspection of the traffic control devices is an important element for ensuring that the TCD's are in place and functioning. However, the RE may not have adequate time to complete a thorough review. Moreover, persons develop expectations, and assume that an element is present or as it is supposed to appear. Therefore, it would be beneficial to have an outside source, in addition to the RE, regularly inspect the layout.

2. Basis for action:
   On-site discussions with RE's uncovered situations where TCD's had been missing or not working, and not noted.

3. Action:
   A specification for all jobs should be contractor safety inspection. Some contractors have taken on the expense of also providing a safety inspection. Inspection of the TCP and TCD's by a third party should occur at least weekly.

4. Potential costs:
Cost is for additional personnel to make a thorough inspection and report. An estimate is that such assessment would require two hours weekly at a cost of between $100 and $200 based on typical hourly costs for contractual work plus travel.

## II. Crash Reporting.

### A. Clearly mark workzone from start to end.

1. Problem:
The police do not know where the workzone starts (although its ending can be assumed to be "End of Construction" sign). As a result, crashes within workzone are not coded as "construction zone related."

2. Basis for action:
Analysis of crash reporting showed that police frequently did not code crashes within workzones as occurring within a construction zone.

3. Action:
The workzone should have a sign marking the starting point (beginning of the approach) and the ending point. On multi-lane highways, there are two zones, one for each direction if construction is occurring on both sides. Police then are trained to report *any* crash occurring within that delineation as "construction zone." Moreover, a workzone crash occurs regardless of the presence of activity.

   Additionally, each workzone should be clearly identified by the IDOT workzone number. This number also would be entered on the PCR which will allow all reports to be separated by zone. In this manner, reports also could be tied to a specific set of construction plans. Under the current method, the only linkage with a specific zone, especially if multiple ones exist along the same roadway, is by milepost which frequently is miscoded.

4. Potential costs:
Additional signing marking the beginning of the workzone is estimated at a one time cost of between $400 and $1,000 for signs which can be reused.

### B. Modify the crash report to meet the Model Minimum Uniform Crash Coding (MMUCC) standards.

1. Problem:
The Illinois Police Crash Report does not provide a separate element for coding workzone crashes. This leads to a failure to code a crash as construction related when it was.

2. Basis for action:
Currently, workzone crashes are under-reported. This was discussed in Chapter 4, and the findings were supported by the special reporting of crashes.

3. Action:
The element to code workzone crashes needs to be separate from other elements. It can have codes to identify the type of workzone, and for a construction zone it would have a place for the workzone number. Police need to be trained to code all crashes within the boundaries as "workzone." Deciding which crashes to exclude can be done at a later point by trained personnel if the step is needed.

4. Potential costs:
The change can be made at the next modification of the PCR. Some changes also have to be made with police training and in programming for the database. However, both tasks should fall within any costs which normally would be associated with the next version of the PCR.

**C. Police need to share every report in a construction zone with the RE.**

1. Problem:
The RE often does not receive copies of crash reports for crashes within the workzone.

2. Basis for action:
On-site observations and discussions with the RE's identified the issue.

3. Action:
Whenever the police take a report for a crash within the designated workzone, they need to send a copy of that report to the RE. If possible, the reporting officer should contact the RE and discuss contributing circumstances. Further, the RE should be trained in the interpretation of crash reports and the use of such reports to correct defects. Copies of the reports and any corrective action taken needs to be made part of the permanent record for construction plans.

4. Potential costs:
Negligible costs because the reporting officer can meet with the RE as part of that officer's patrol.

**III. Educating the motorists.**

**A. Use Variable Message Signs (VMS) to note when queues are present or other unexpected changes occur.**

1. Problem:
Motorists appear to ignore permanently placed warning signs. They may not be prepared for unexpected events at the workzone, such as queued vehicles.

2. Basis for action:
Videotaping motorists approaching a workzone, the literature, and discussion of specific issues during on-site visits provided insight into the problem.

3. Action:
Use variable message signs (VMS) to display messages which will catch the attention of motorists. The literature suggests that permanently displayed warnings, especially if they are static, are not always noted by motorists. These findings also are supported anecdotally by the RE's. VMS are needed, especially when queues might be present and hidden from the approaching motorists' view. The signs should not be used unless a problem needs attention.

   Although significant effort has been directed toward protecting workers in construction zones and to reminding motorists to reduce speeds, very little education and information appears related to driving in workzones. Increased public information regarding how to approach and negotiate a workzone is important.

4. Potential costs:
Variable message signs are expensive to rent (one RE quoted the cost at $1,000 per day). They cost between $20,000 and $40,000 to purchase. However, the construction budget should include the use of such signs especially under heavy traffic conditions.

## IV. Working Area.

### A. Use "Jersey" type barriers to separate traffic from workers.

1. Problem:
Most of the crashes involving construction personnel arise because the workers are not separated from the motorists by an object which prevents incursion into the work area.

2. Basis for action:
The literature and review of Illinois crash data shows that there are few worker injuries when they are separated from the motorists by some form of barrier.

3. Action:
"Jersey" type barricades are more effective than cones or barrels for separating opposing traffic and traffic from the workers. The barrier represents an almost immovable object which prevents penetration into the working area. The one major problem with using the concrete barriers is the cost of installation. There are now collapsible plastic barriers that are filled with water. These are easy to use and move.

   However, the separation is not effective if either workers or their equipment can conflict with traffic. Drivers navigating through the workzone have enough distractions and multiple, unfamiliar driving situations without also having to be cognizant of construction interference. Unless needed, and unless an adequate entrance and access space is available, construction vehicles should not be entering or crossing the traffic stream other than through the entrance or exit of the actual construction area itself. Workers should have no reason to be anywhere but inside the separated area. The IDOT policy of requiring workers to park inside the zone or at designated off-road sites outside the zone is excellent.

4. Potential costs:
Installing barriers can run $1,000 per 100 feet and cost $500 to $1,000 per change. An alternative to concrete barriers is the use of collapsible ones (one estimate suggested $2,000 or more per 100 feet). These are easier to install and, therefore, to change (stiffening comes from filling them with water). Initial costs of changing to collapsible barriers from the current concrete ones could be high (costs needs further research). However, once the change is made, lower costs of installing and operating them ultimately might offset those one-time costs of changing.

**B. When barriers are in place, provide escape areas.**

1. Problem:
The barriers do not provide motorists with a means of escaping from the traffic stream either for an emergency or to avoid a crash. Moreover, the lack of escape allows no place for motorists involved in a minor crash to move so as to open the roadway for continued travel.

2. Basis for action:
Review of the crash reports with supplemental contributing elements highlighted the problem. In addition, such pull-out areas also have been used in other construction projects.

3. Action:
Pull-off areas need to be established at regular intervals. These will allow room for a disabled motorist to sit, and will provide some space to escape. Pullouts could be provided frequently. Unless the workers are in the entire work area, only the small section where they are present would not have pullouts.

4. Potential costs:
Costs of occasionally changing barriers as work progresses might be $500 to $1,000 per change if concrete barriers are used (should be less expensive where collapsible barriers are present). This process, however, may be needed only a few times during the project.

**C. Shield the work from view of the passing motorists.**

1. Problem:
Motorists are distracted by the activity and slow or stop unexpectedly, leading to crashes.

2. Basis for action:

Supplemental reporting as part of the special crash reporting for the project indicated distraction as an important contributing factor to crashes.

3. Action:
Such gaping can be eliminated by more effective screening of the work area. For example, a two-foot high, lightweight fine mesh screen strung along a "Jersey" type barrier wall where work is occurring would be easy to install and move. The barrier wall already provides approximately three feet of height, and the remaining two feet would be sufficient to prevent viewing of work by most of the motorists.[17] When barrier walls are not used, a five-foot screen could be installed on the barrels. Again, the purpose is not to block the entire construction area, but to prevent stray viewing of active work by most passing motorist.

4. Potential costs:
Costs of purchasing the equipment could exceed $2,000 to $10,000 for the material and supports for each unit. However, the equipment is reusable; therefore, the costs will be spread over many jobs.

**D. Reduce the length of lane blockage.**

1. Problem:
In some of the observed sites, traffic was required to use one lane of two even though the construction affected only a small portion of that blocked roadway. Under congested conditions, this provides more opportunities for collisions. When work is not in progress or obvious along the blocked roadway, motorists might tend to ignore the speed limit and possibly consider other workzone TCD's as not important.

2. Basis for action:
Study of the literature suggested that those with very long workzones, e.g., five or more miles in length may have more crashes per mile than those zones which are shorter in length.

3. Action:
Where long stretches of roadway will be under construction, but the construction will be limited to shorter segments, the layout should consider shorter lengths of lane blockage to be moved as construction progresses.

4. Potential costs:
Costs for the TCP and use of TCD's likely would be lower because fewer warning devices are needed at the site.

**E. Use variable speed limits (VSL) for the working area.**

---

[17] This shielding of the working area was an unintended result of using headlight deflectors on the lane separation barrier for the Illinois Tollway, I-94 north of Deerfield Road.

1. Problem:
When work is not in progress, motorists begin disobeying the posted lower limits.

2. Basis for action:
Discussion with RE's at the on-site visits, the literature, and review of special crash reporting (that included the supplemental reports done for the project) highlighted the problem. In the case of crash reports, speed within the working area did not appear to be a contributing factor to crashes.

3. Action:
Use VSL in the workzones to raise or lower speed limits depending upon whether or not work is in progress and when congestion is present. These signs then could display a normal speed limit when conditions allow it to be posted, and lower it if work or congestion warrant changes. Moreover, the changes could reflect the speed limit most appropriate for the site. Changes in speed limits under congestion could be done automatically through the use of vehicle flow or speed detectors and an algorithm to set the proper speed.

4. Potential costs:
Costs of $20,000 or more possible for variable message signs (VMS); however, a more formal assessment of costs currently is in progress in a National Cooperative Highway Research Program (NCHRP) investigation 3-59 which is developing standards for installing, operating, and evaluating VSL in workzones.

## V. Approach and Taper

### A. Keep lane shift and reduction of lanes consistent.

1. Problem:
Changing how the lanes are reduced, i.e., first a right merge, then a left merge may be confusing to drivers who use the roadway frequently.

2. Basis for action:
The issue was identified during discussion with RE's at the on-site visits.

3. Action:
Once a lane change and reduction configuration is made part of the layout, it should remain throughout the project. The literature has some discussion whether merging should be from the right or the left. Merging from the left to right lane may represent a more common maneuver, but it is more difficult for truckers because of their blind spots.

4. Potential costs:
There may be savings from not having to reset the layout once it is in place. Using the dynamic merge concept (Indian DOT) with revised "Workzone Speed Limit" is approximately $4,000 per sign.

1. Problem:
When lanes are narrowed after a taper, especially where higher approach speeds are present, drivers of semi-trailers appear to have a problem stabilizing the tracking of their unit after shifting the lane. At one workzone, infringement on an unstabilized shoulder, in part, contributed to a fatal crash.

2. Basis for action:
Discussion with an RE on-site and review of crash reports indicated the immediate narrowing of the lanes may have contributed to collisions involving trucks.

3. Action:
Instead of narrowing the lane to 12 or 11 feet immediately after the taper, gradually reduce the width from at least 15 feet to the final width over several hundred feet. This provides room for the driver of a semi-trailer, and especially a "double-bottom" to bring the trailer(s) into the same track as the tractor.

4. Potential costs:
None unless a lane is not available and the shoulder has to be stabilized. Normally, two lanes have been reduced to one and part of the other lane can be used.

**C. Reduce a lane of travel one at a time.**

1. Problem:
When more than one lane is being dropped, doing both at the same location creates more opportunities for collisions and vehicle interference. The latter can lead to increased congestion.

2. Basis for action:
Videotaping driver behavior at the location where two lanes were dropped at the same time showed apparent poor merging tactics.

3. Action:
Drop a lane, then allow motorists a short segment with the one less lane of travel before dropping the next lane.

4. Potential costs:
Some additional traffic control devices may be required to properly mark the lane changes. An estimate of such costs lies between $1,000 and $2,000 plus some added maintenance costs over the life of the transition. However, the number of times it is needed are so infrequent, that the costs are not an important consideration.

**D. Use VSL to reduce speeds in the approach.**

1. Problem:
Speed limits in the approach may be too high to allow proper maneuvering through the transition portion of the workzone, but reducing speed is more important when queuing is present.

2. Basis for action:
   The special crash reporting for the project and videotaping driver behavior of persons approaching the transition area.

3. Action:
   A review of the specially collected crash reports identified speed in excess of the speed limit as a contributing circumstance to only one crash occurring within the working area. On the other hand, high speeds appear to be a contributor to crashes occurring in the approach and transition, especially on Interstate highways. Speed reduction in the approach can be done through VMS. One or more would be placed on the approach to the transition zone. Speeds could be changed automatically based on sensor input when queuing is present or where conditions warrant posting a speed limit other than what would be considered standard for the approach. These same signs can be used to inform motorists of unusual conditions (see III. Education) and to control speeds within the working area (see IV. Working Area).

4. Potential costs:
   Although costs for such signing have not been derived, a National Cooperative Highway Research Program (NCHRP), project 3-59, will be examining the costs and effectiveness of VSL in workzones. Use of VMS can be $20,000 or higher.

### E. Require alternate merge.

1. Problem:
   The videotaping provided significant insight into how motorists behave during the approach and merge. In situations where no queues exist, merging took place normally well before the taper and without interference to traffic flow. However, with increased traffic and queuing, the merging behavior changed and created more opportunities for crashes. At this time all drivers need to merge at a common point. While early merging causes no problems, merging after the queue starts is disruptive if it occurs in more than one location.

2. Basis for action:
   Videotaping driver behavior and analysis of specially prepared crash reports for this project suggested that a smooth merging improved traffic flow at the end of the taper.

3. Action:
   Even when a driver waits until the taper, the merge can proceed smoothly provided it is done alternately. Likewise, motorists merging well before the taper when adequate gaps exist also generate no interference. The Indiana system of merging or "dynamic merge" helps promote earlier merging. However, the equipment for it costs approximate $4,000 per sign. The merge also requires periodic enforcement to ensure that it continues to operate as intended. An evaluation of its effectiveness has not been done.

that it continues to operate as intended. An evaluation of its effectiveness has not been done.

As an alternate, once the driver has committed to a lane, all merging then should occur at one location. This can be controlled through the use of road striping and signs, or with physical barriers. The latter, however, represents another obstacle which can be struck by motorists. Alternate merging needs to be backed legally so that enforcement can be done. The signs used would have messages advising motorists to "remain in lane," drive "at speed" to the merge point," and finally to "alternate merge."

One means of establishing alternate feeding is to use ramp metering signals for each lane. Under normal conditions, drivers would alternately see a red and then a green which would be sequenced based on the speed and smoothness at which traffic is merging. A second signal placed back in the approach could be used to slow a driver who is approaching the end of a queue too fast.

4. Potential costs:
The Indiana merge requires the use of three or more "Work in Progress Speed Limit" signs on trailers with additional equipment to allow them to detect queue build-up and communicate with the next sign upstream. Costs are estimated at $4,000 per trailer which carries the sign.

If the alternate merge used in Pennsylvania is done instead, then costs must be incurred for the signs. However, this represents a one-time cost or painting by the sign shop. The signs are reusable.

## F. Concentrate enforcement on the merge and taper portions.

1. Problem:
Probably more attention is paid to vehicle speeds, especially in the working area, than any other driver behavior. When police are hired to patrol the scene, most, if not all, of their efforts are within that area. State laws reinforce the effort by doubling the fines for *speeding* in the working area. Yet, a review of the specially collected crash reports suggested that speeding in the working area was not a problem. Instead, several classes of traffic law violations occurring before the start of the working area, including speeding, were identified as contributing circumstances in the approach and taper.

2. Basis for action:
Analysis of the supplemental reports submitted with the specially prepared PCR's, and videotaping driver behavior indicated several traffic law violations which could lead to crashes.

3. Action:
There are several actions which represent violations of the law in the approach and taper portions for which increased enforcement might reduce the number of crashes. If the alternate merge is required, this adds one additional enforceable action. Because police already provide presence at workzones, this action requires only changing their

a. Enforce speed limits posted for the approach and taper.

b. Enforce an alternate merging law. In the act of merging, motorists take two actions which have potentially negative consequences: 1) forcing a second vehicle into a gap, and 2) failure to create a gap. These practices can increase travel delays and, more importantly, could trigger negative responses translating to aggressive driving.

c. Reduce vigilante behavior by requiring trucks to merge well before the start of a queue, e.g., "No Trucks in Left (Right) Lane" and enforcing "impeding traffic" laws. Vigilante behavior, as described earlier, occurs when motorists try to block the merge lane, or drive in the merge lane at the same pace as those vehicles in the through lane to prevent motorists in the merge lane from reaching the transition ahead of others in the through lane. Because there is no law prohibiting such movement to the end of the queue in the merge lane, this action to impede traffic is illegal and increases the risk of aggravating the affected motorists.

4. Potential costs:
The costs already are incurred when police are hired to patrol the workzone.

# 10. A Model for Workzone Traffic Control

## Limitations in the Current Methods of Assessing Workzone Safety

Motor vehicle crashes occur mainly because of driver error, but such errors are increased and their results exacerbated by workzone conditions, including type and intensity of work activity at the time of the crash, the type of traffic control devices (TCD) used and the layout of the workzone.

Safety in the workzone is an important issue. The challenge of enhancing safety is made necessary by the aging highway infrastructure and amplified by the quickened pace of construction and rehabilitation made possible by the Transportation Efficiency Act for the 21st Century (TEA 21) and Illinois First funds. Past studies of the safety of motorists and construction workers within workzones have been limited to statistical analyses of workzone crash severity, crash type, and the effectiveness of countermeasures. All of these studies primarily provided information on the causality of these crashes, which earlier research had addressed. Most importantly, the police crash reports (PCR) used for these analyses has not provided adequate information to help locate where within the workzone the crash occurred and the relationship between the workzone layout and events leading to the crash.

Given some assumptions, Illinois workzones, in terms of severity of crashes, appear to be no more dangerous than any other roadway location. As with any crash analysis, some locations are more dangerous than others, and the same would apply to workzones.

Desirably, better data can be used to categorize characteristics of crashes by workzone type and to build linked roadway inventories that eventually can be used during integrated analyses to modify guidelines and standards to enhance workzone safety. While such "off-line" research studies are likely to continue to produce long term benefits, this study suggests that there are important opportunities to enhance safety at active workzones by making quick and effective use of the incremental and often locally unique information contained in the first crashes which occurred at a given workzone. By focusing primarily on off-line research using a comprehensive data set, insufficient attention may be given to careful, local collection and analysis of data, and, more importantly, to empowering the right parties to analyze and use that information immediately. In essence, while much has been learned about workzone safety from the literature, history, guidelines and standards, there are also important opportunities to learn from experiences and practices at individual workzones.

This chapter introduces a process model to collect, analyze and apply traffic safety and performance data during the entire life of specific workzones. The intent of this model is to accelerate learning, taking maximum advantage of immediate events at workzones to make adjustments to enhance and ensure safety. In the long run, the crash data and measures of effectiveness collected should contribute to a super set of accurate data which could be used to measure workzone safety, as well as a set of identified problem-solution pairs, which in turn should support the improved design and operation of future workzones and avoid or minimize problems which emerge after the work has started.

The process model incorporates many of the recommendations presented both in Chapter 7 and the previous chapter. It shows how the recommendations can be applied. Most importantly, the model provides a methodology for enhancing workzone safety.

## Temporal Patterns of Excess Workzone Crashes

Examination of temporal patterns of excess workzone crashes (Figure 9, A through C) revealed substantial month-to-month variation, and major differences in temporal patterns across workzones. These findings strongly suggest the value of closely monitoring workzone safety, collecting detailed data, and investigating crashes at each workzone to detect crash patterns quickly and find effective responses to them. For example, during the first three months of operation of the workzone on I-74, eight crashes occurred, including one fatality. Police crash reports showed that four crashes occurred during the first month, three during the second and one during the third month. This is an example of the pattern of high initial crash occurrences as depicted in Figure 9A. The resident engineer reported that the soft shoulders contributed to loss of control. Adding wider and stronger shoulders addressed the problem. However, a delay in the intervention may have contributed to the unnecessary crashes.

This example suggests both the importance and the potential value of carefully investigating each crash, starting with the first occurrence at a workzone, to identify the contributing factors and identify needed changes in workzone configuration and traffic control plans (TCP). Such immediate and reactive investigative efforts help identify problems early and thus reduce the number of future crashes. Further, that problems in the noted workzone occurred outside the working area, demonstrates the importance to collect data over an area significantly longer than that covered by just the working or construction area.

## Process Model

A process model for continuously monitoring workzone safety would allow detection, learning from, and responding to problems when they occur. The process model proposed (Figure 10) has the following features:

- Builds a crash rate database in advance of the construction project to serve as a basis for assessing workzone performance.
- Develops and continuously adapts workzone traffic control plans (TCP) to minimize the possibility of crashes.
- Uses exposure measures for monitoring the impact of a workzone on the sub-network in its vicinity.

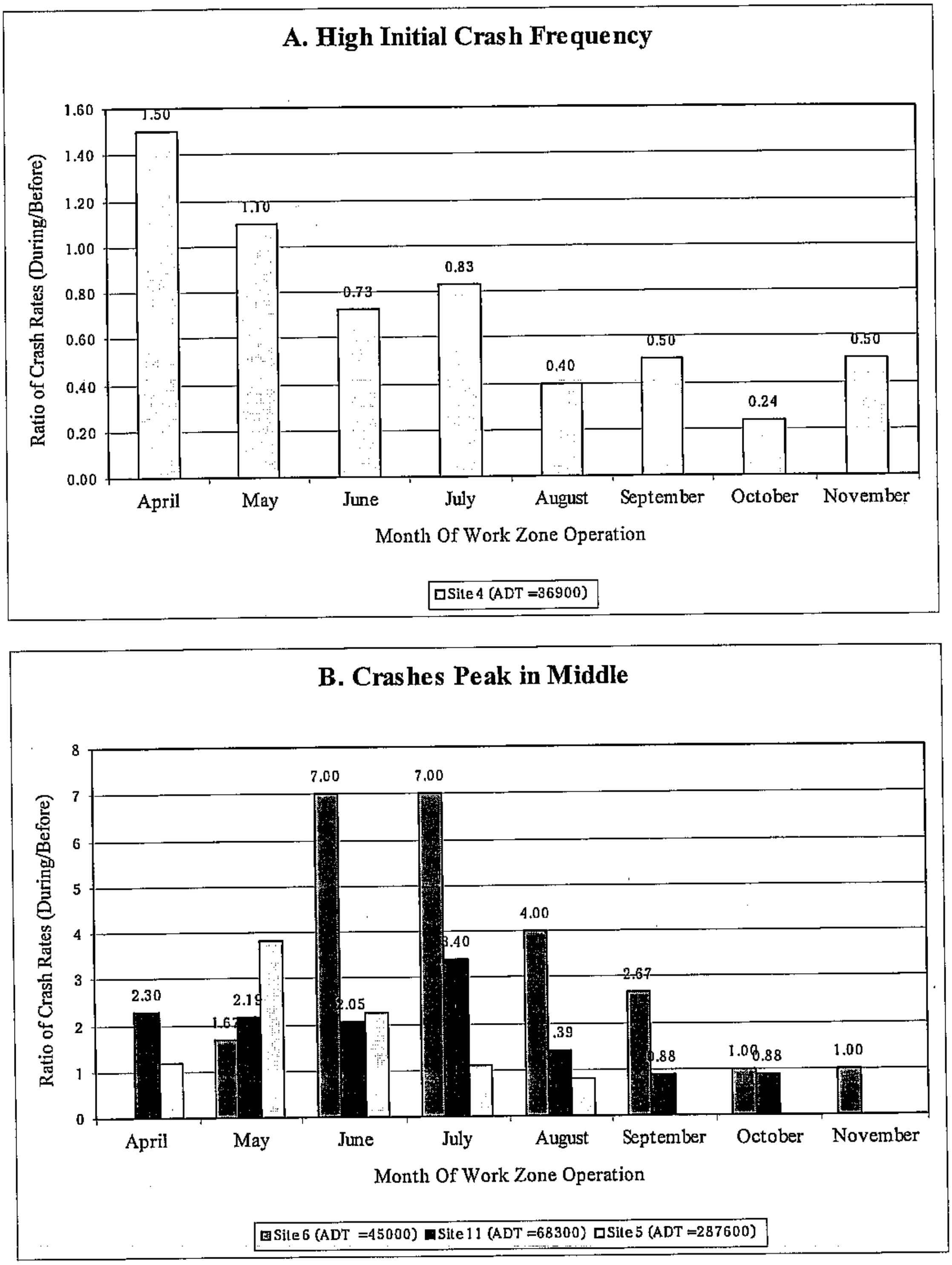



**Figure 9**
**Workzone Crashes by Month of Occurrence**

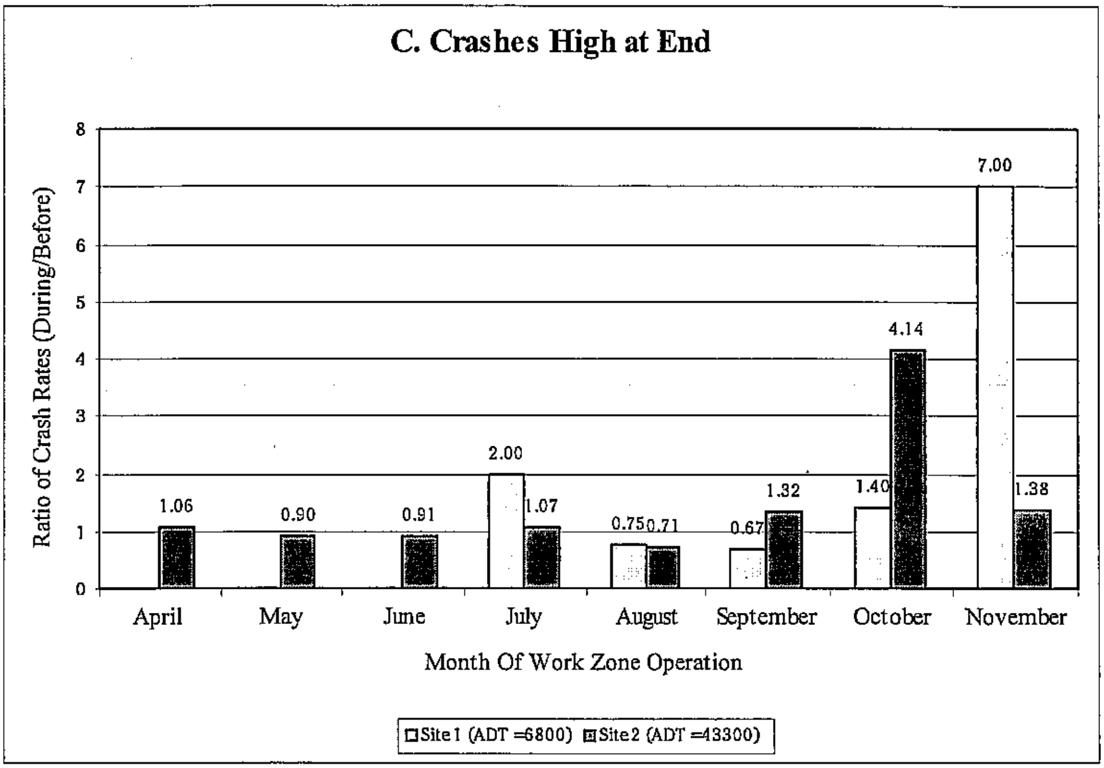


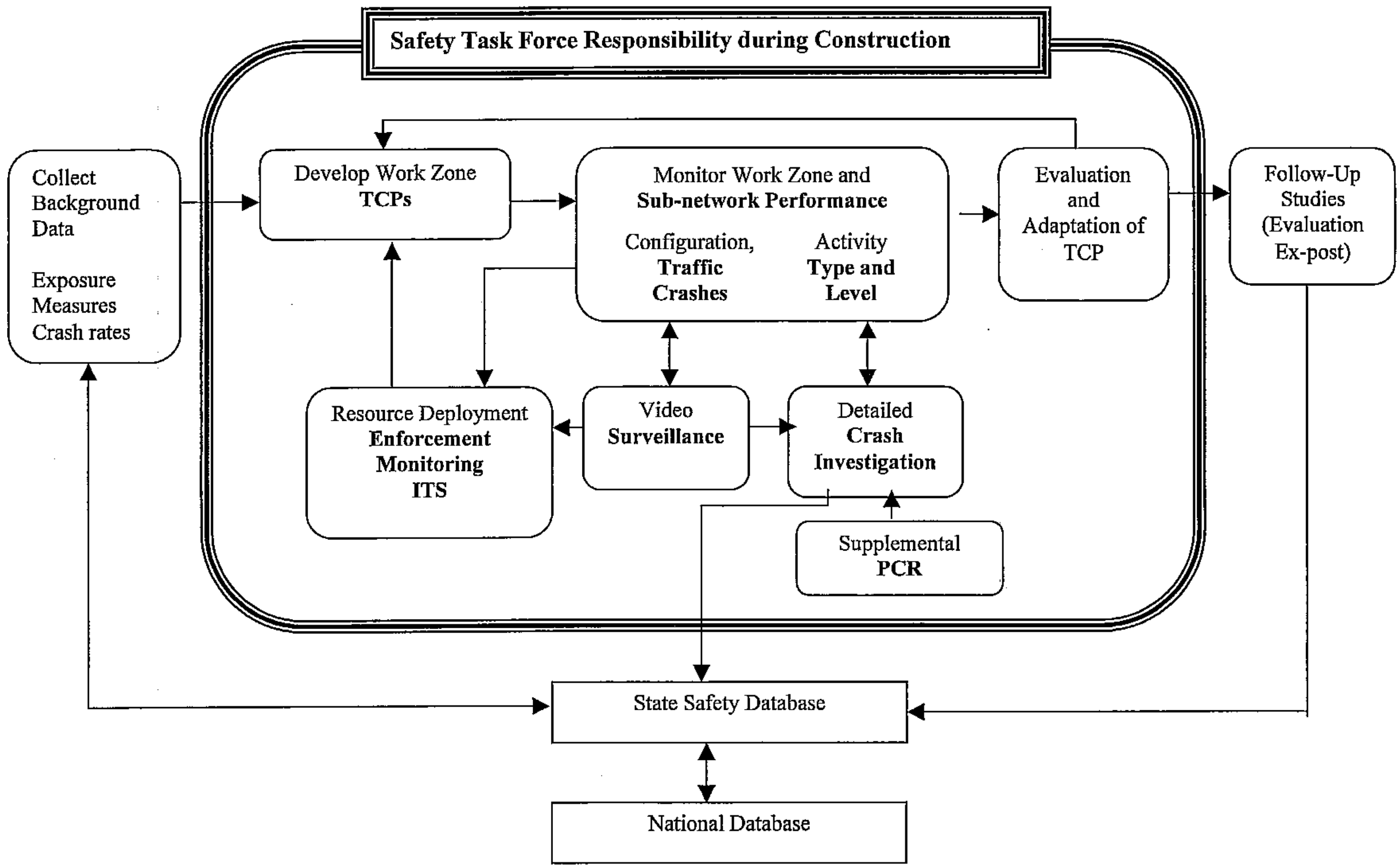

**Figure 9 (cont'd)**
**Workzone Crashes by Month of Occurrence**

- Establishes clear responsibility for monitoring and managing safety at particular workzones through a project safety task force.
- Uses existing technology to continuously monitor the workzone safety.
- Uses monitoring data to guide deployment of enforcement resources and Intelligent Transportation Systems (ITS) traffic management devices.
- Applies enhanced crash reporting for workzone crash investigation.
- Reports processed information to the appropriate agencies to contribute to a database for larger scale meta-analyses.

Key components of this model are discussed in the following sections.

In addition to the discussion, Appendix G contains a workzone traffic control plan as originally drawn and then modified during the project. It shows how the standard layout can represent changes in traffic controls during construction, results of monitoring traffic behavior, crashes, and enforcement used.

**Figure 10**
**Process Model for Enhancing Workzone Safety**



## Impact of the Workzone

Temporal knowledge. Investigating the relationship of the construction zone safety measures to vehicle crashes and developing recommended countermeasures requires comprehensive collection of data for three time periods: *a-priori, current, a-posteriori*. *A-priori* data is important because workzones alter the normal character of a transportation facility, and can cause serious traffic disruption and increase in crash rates. An accurate assessment of traffic and safety conditions prior to the start of the work can provide a baseline for evaluating the immediate impact of the workzone on motorists' safety. Using crash rates to compare changes in safety over time requires accurate knowledge of both crashes and the average daily traffic (ADT) on the facility prior to the beginning of the work. Similarly, *current* and *a-posteriori* data are required for precisely determining workzone crash rates and types, and for evaluating the crash experience after the roadway improvements.

Spatial knowledge. In addition to *temporal* knowledge of the impact of the workzone, there is also a need for *spatial* information. Impacts of a work area almost always extend beyond its boundaries, i.e., (advance area, taper or crossover, work area, and exit), affecting the traffic conditions over a larger sub-network. Moreover, Ullman (1996) showed how closure of lanes over the long term resulted in traffic diversion which in turn can affect measures of safety. Therefore, the network surrounding the workzone can be affected negatively. Limiting the *spatial* monitoring to the construction area may not provide a complete understanding of its impact, because while the data may show that the zone itself is safe (has low crash rates), the problem might manifest itself on streets in the vicinity of the zone because of excess traffic, limited capacity, unresponsive control devices, sensitive neighborhoods and other factors. Workzones can no longer be viewed as isolated phenomena but rather as events which can produce impacts extending to the sub-network in the vicinity.

## Responsibility for Managing Workzone Safety

To provide continuous assurance of workzone safety, there is a need for an active agent who makes use of exposure, performance, and safety information throughout the life of the project, i.e., planning, construction, and post completion. This can be done through a project safety task force including the district supervising traffic engineer, the resident engineer, the contractor's representative, and an independent safety inspector who should be hired by the IDOT on a consulting basis for regular inspections of a few ongoing workzones in the same area and who must report the findings to the IDOT. The safety task force brings together the key players to create a decentralized council, which, like the National Transportation Safety Board (NTSB), will be responsible for determining the causality of workzone crashes and driving problems, and who will recommend immediate changes to traffic control plans (TCP).

By being involved in the planning stages to recommend the safety measures to be used for the workzone, the safety task force may anticipate problems. The examples relating to sign and layout on US 67 noted in chapter 7 might have been avoided had the safety task force been involved with the evaluation of the safety measures recommended by the TCP. At least some of these crashes might have been avoided.

In addition to evaluating the adequacy of the standards of the TCD to be used, the safety task force can recommend the use of some TCD over others. Again, conversations with resident engineers led to conclusions that the use of VMS might be preferable to static warning signs, at least along the approach and perhaps inside the work area. The safety task force would allow the resident engineer to voice his or her recommendations based on field experience. It should also hold the power to command additional resources where needed.

## Monitoring Workzones

Continuous monitoring. The role of the safety task force extends throughout the construction period to monitor the safety of the workzone. Currently in Illinois, the resident engineer is charged with inspecting the workzone and the traffic control devices (TCD) on a daily basis, while the supervising traffic engineer inspects them monthly. As noted by Hall and Lorentz (1989), routine inspections, contrary to the general belief, might induce more deficiencies in TCD quality because of involuntary negligence as a result of great familiarity with the site. Based on information gained from sites visited, IDOT should consider hiring independent safety inspectors for periodic inspections of the TCD. Costs for hiring the safety inspector may be less than the costs incurred through increased crash liability resulting from defective TCD.

However, these periodic inspections provide fragmented information on the level of safety. Continuous monitoring which takes advantage of the existing technology can shed the light on problems not otherwise captured during periodic inspections. Such monitoring can put occasional crashes in context to facilitate and sharpen the analysis and interpretation of the contributing factors. The videotaping of the workzones visited and the analysis of the crashes provided information that could not be obtained from periodic visits. For example, at one of the sites, the workers were observed to cross the road frequently, putting themselves and the drivers at risk of a crash. Such video monitoring may help the safety task force.

Cameras monitoring the workzone at different locations are valuable tools to evaluate the overall safety of the workzone and to assess the contributing factors faster and more accurately. The task force can use videotapes as evidence to diminish uncertainty associated with the crash reports. They can also detect dangerous driving behavior and assess worker safety to identify appropriate measures before crashes happen.

An important aspect of monitoring the workzone performance is measuring the effects of TCD's on the drivers' behavior. For example, speed-sensing devices can establish the relationship between a type of TCD and the resulting speeds or speed differentials. If it appears that such a TCD contributes to increasing crash risks, appropriate action can be taken. Coupled with the video cameras, the speed-sensing devices can be used to identify risky drivers behaviors (such as rapid approach to end of the queue, rapid approach to the merge, late merging and others), which may require changes in the TCP or the workzone configuration.

Deploying resources. To make the best use of resources, monitoring should occur primarily in periods during the life of a workzone when it is likely to provide the most useful information on workzone hazards. Logically, monitoring is likely to provide the greatest payoff at times of change – initiation of workzone, changes in configuration, changes in activity levels.

Confirming this argument is possible by examining the ratios of crash rates during and before workzone activities and relating these to workzone activity and configuration changes. The data collected for the selected sites shown earlier in Figure 8 (shown previously) suggest that patterns of occurrences follow at least three types: high initial, peak in the middle, and high at the end. This suggests the potential value of allocating monitoring to periods of crash rate peaks when it is most likely to identify the cause of the increase in the ratio and guide the search for appropriate countermeasures.

In this study, no information was available on the work schedule at each site, the monthly ADT, and the type of traffic control devices used. Therefore, causality of each of the three patterns can only be hypothesized. However, in the long run the process model can gather sufficient data to categorize crash rate patterns by type of roadways, ADT, length of workzone, duration and thus identify periods during which monitoring and investigating are likely to be most beneficial.

Guiding deployment of enforcement resources. Resources for incremental traffic enforcement, especially through use of "hire back" dollars, are limited, so it is important that they be deployed in the most effective manner. Information from the workzone monitoring program can be used to guide these allocation decisions, determining the number of police officers required, identifying locations that contribute most to crash risks, and providing sufficient curb space to pull over the violators. Decisions about hiring and deploying police officers can be informed by observing where potential problems might occur when intense work activity, congestion, or specific types of lane closures are in progress. For example, speed profiles collected during the monitoring of the workzone can be analyzed to determine the best hours for hiring off-duty police officers and identifying locations inside or around the workzone with the highest number of speed limit violations.

Intelligent Transportation Systems (ITS). Evolving Intelligent Transportation Systems (ITS) offer new opportunities to meet the information needs and requirements of the workzone traffic management as well as to implement real-time demand and condition-responsive network controls. While rarely used in Illinois today, these technologies can be deployed both to collect real-time data and to use that data to implement more efficient traffic management strategies. For example, portable ramp metering to control the merging of vehicles may reduce the number of rear-end and sideswipe crashes.

Similarly, portable intelligent signing which signals the end of queue to the incoming flow may reduce the number or rear-end crashes by causing drivers to slow down. VMS driven by the prevailing traffic conditions can warn or require upstream traffic to merge earlier.

Video monitoring can also be used to enhance driver's understanding of upcoming traffic conditions and compliance, by using large-scale video screens located upstream of the workzone to display conditions inside the workzone. Presented with visual evidence, the drivers might pay better attention to signing and marking.

Monitoring can be used to assure that the TCP is realistic relative to workzone needs. This helps maintain a trusting relationship between the drivers and the warning devices.

## Enhanced Crash Reporting

A key to successfully understanding the relationship between crashes and the workzone lies in having sufficient data about crashes from which contributing circumstances can be derived. Although the police crash report (PCR) provides information about characteristics of crashes such as time, weather, *etc.*, there are additional factors which may be crucial to understanding the events leading to a workzone crash. For example, the placement of barriers or other TCD may be important contributing factors not normally included in a PCR.

To assist the safety task force in determining the cause of workzone crashes, a supplemental police crash report, such as the one developed during the study and shown in Appendix C, should be used to gather data not otherwise available from the PCR. This supplemental report specifically includes possible contributing factors in the workzone, and thus it should help identify problems and formulate appropriate countermeasures.

It is important for crash investigation to capture information on the causes of crashes otherwise not available from the coded police crash reports. From the analysis of the eight *coded* police reports at the workzone which had inadequate lane width for trucks, the traffic control devices were working properly in 75% of the cases and that the driver was not at fault in 50% of the cases. However, the officers' diagrams in the *narrative* part of the police crash reports suggested that a narrow lane and soft shoulder contributed to the crashes.

The narrative part of the police crash report is based on the officers' interpretation and judgment.[18] Although the officer will make use of primary evidence (such as eyewitness reports and measurement), he or she will use some judgment in the interpretation and analysis of the evidence. Even the supplemental form, which serves to constrain and direct the officer's judgment, cannot account for all possible contributing factors. Therefore, retraining of officers for collecting workzone crash data needs to emphasize the importance of the narrative component of the PCR along with appropriate diagrams, to be sure that a complete and accurate description of the event is provided.[19] Furthermore, it should be the responsibility of the safety task force to analyze the information provided by the PCR and to further investigate a crash immediately after the first occurrence.

The proposed process model primarily will help assure that all pieces of information first are accurately reported, and second, clearly identify links between one piece of information and another. One critical link is the relation between the crash site and location in the workzone. One problem which arose during the research was an inability to link crash reports and workzones. Where actual construction plans were reviewed, there were cases where the crash as reported could not have occurred in the zone; yet, the crash was coded as a "workzone crash." The workzone number would help eliminate this problem.

---

18 If the crash does not result in an injury or require a tow, the police officer can complete a shortened version of the PCR which does not require a narrative and diagram.

19 Perhaps IDOT needs to change its crash reporting policies to require a complete, not shortened, crash report be filed for every crash occurring within a workzone. Moreover, any crash occurring within the entire workzone limits must be reported as a workzone crash.

Currently, a number of organizations collect workzone data for analysis. For instance, the Federal Highway Administration (FHWA) developed the Highway Safety Information System (HSIS) to maintain a database on workzone crashes. In the process model, data on characteristics of crashes would be reported in a format consistent with the current standards of the existing institutions. Figure 10 (previously shown) illustrates how the data should be reported to state and national databases for future use. As new data are added, standards can be revised, deleted, or new ones established.

## Concluding Commentary

Workzone traffic controls and the workzone traffic control plan appear to provide adequate information regarding the construction area. The TCD and TCP have been developed from significant experience across the nation with construction projects and from a substantial body of research. Research based on crash data made available from IDOT and from special crash reporting (with supplemental forms) suggests that crashes are more likely to occur when workzones are present than when they are not. Moreover, overall, crashes do not appear to be any more severe in terms of injuries than when workzones are not present. Within the actual work area, more than 85% of all crashes are property damage only which is substantially greater than the percent for all crashes on similar roads. The largest single area of concern is the approach and taper. Supplemental reporting accompanying crash reports suggested that the greater dangers existed at these locations rather than within the construction area itself. On roadways where the construction was separated from the traffic by "Jersey" type barriers, almost all of the crashes involved transiting vehicles; workers and their equipment rarely were involved and when so, they were outside of their assigned areas.

What appeared to be more pressing problems are: 1) tailoring the TCP and TCD to specific locations, 2) gathering and using data about crashes, and 3) modifying motorists behavior. Tailoring of devices was discussed in the previous chapter. Likewise, crash reporting was addressed in several chapters throughout the report. The two most notable deficiencies with reporting was that crashes occurring within workzones were not reported as such (under one estimate, as high as 85%), and even when reported as occurring in a "construction zone," were lacking in sufficient detail, or were improperly located, so as to be of limited value.

Chapter 8 was devoted to motorist behavior with the concentration on the approach and taper itself because the more serious crashes appeared to have occurred at these locations. It is then the approach and taper where the research suggests that most value will be achieved by 1) improved TCD that helps slow and guide motorists into the new configurations, 2) crash reporting that pays attention to this area, and 3) enforcement devoted to the approach rather than inside, especially where physical separation of vehicles and works occurs.

Finally the report has set forth a number of recommendations and a process model for continuously monitoring a particular workzone and investigating workzone crashes by collecting, analyzing and utilizing experiences at an individual workzone for safety enhancement. In addition to developing exposure measures and formulating recommendations to evaluate safety measures during the planning and designing stages of the workzone, the process uses continuous monitoring to detect, investigate and analyze workzone crashes and identify countermeasures.

Two key components are a task force charged with the responsibility for safety at each workzone, and an enhanced crash reporting scheme.

This process offers a constructive method for limiting the number of crashes at specific workzones. By capturing, analyzing and accurately reporting the workzone crash information, the most promising targets for future research can also be identified. Eventually, with an accurate data set, the crash rate patterns of a given workzone might be anticipated, which in turn may allow for cost effective monitoring of workzones and the investigation of their crashes while enhancing workzone safety.

## References

AIPCR. *Securité sur les chantiers routiers.* Paris: Association Mondiale de la Route, 1996.

Benekohal R. F., L. M. Kastel, and M. I. Suhale. *Evaluation and Summary of Studies in Speed Control Methods in Workzones.* Urbana-Champaign, IL: Department of Civil Engineering, University of Illinois at Urbana-Champaign, 1992.

Buritt B. E., and H. A. Guenther (1987). "Traffic Control Management Through Construction Zones." *Transportation Research Record 1148.* Washington, DC: Transportation Research Board, 25-29.

Byrd, P. S., D. R. Jessen, P. T. McCoy. and G. Pesti (1999). "Traffic Flow Characteristics of the 'Late Merge' Work Zone Control." *Transportation Research Record 1657.* Washington, DC: Transportation Research Board, 1-9.

Dixon K. K., J. E. Hummer, and A. R. Lorscheider (1996). "Capacity for North Carolina Freeway Workzones." *Transportation Research Record 1529.* Washington, DC: Transportation Research Board, 27-34.

Dixon K. K., and A. R. Lorscsheider (August 1995). " The Effectiveness of Switching Lane Alignments in Workzones." *Compendium of Technical Papers, ITE 65th.* Washington, DC: Institute of Transportation Engineers, 123-126.

Dudek C. L., E. C. Noel, O. J. Pendleton, and Z. A. Sabra (1988). "Speed Control Through Freeway Workzones: Techniques Evaluation", *Transportation Research Record 1163.* Washington, DC: Transportation Research Board, 31-42.

Ellis, R. D. Jr., and S. J. Amos (1996). "Development of Workzone Lighting Standards for Nighttime Highway Work." *Transportation Research Record 1529.* Washington, DC: Transportation Research Board, 35-42.

Faghri A., and M. J. Demetsky. "Expert System for Traffic Control in Workzones" *Journal of Transportation Engineering* 116, No. 6, 759-769.

Federal Highway Administration (FHWA). *Design and Operation of Workzone Traffic Control.* NHI Report No. 38003, Washington, DC: Federal Highway Administration, 1988.

Garber N. J., and T. H. Woo (1991). "Effectiveness of Traffic Control Devices in Reducing Accident Rates at Urban Workzones," *Transportation Quarterly* 5, No. 2, 259-270.

Garber N. J., and T. P. Surbhi (1995). " Control of Vehicle Speeds in Temporary Traffic Control Zones Using Changeable Messages Signs with Radar." *Transportation Research Record 1509.* Washington, DC: Transportation Research Board, 73-81.

Graham J., F. Hanscom, and D. Stout (September 1993). "Highway Evaluation of Maintenance Workzone Safety Devices." *Proceedings of the Strategic Highway Research Program (SHRP) and Traffic Safety on Two Continents,* vol. 1, Linkoping, Sweden: Statens Vagoch Transportforskningsinstitut, 143-157.

Graham J. L., J. Migletz, J., and D. W. Harwood (September 1993). "Procedure for Determining Workzone Speed Limits." *Compendium of Technical Papers, ITE 63rd.* Washington, DC: Institute of Transportation Engineers, 214-218.

Graham J. L., J. Migletz, and J. R. Loumiet. *Application of Advanced Concepts and Technologies to Maintenance Workzone Safety.* Preprints, 69th Annual Meeting, Washington, DC: Transportation Research Board, 1990.

Graham, Jerry L., Robert J. Paulsen, and John C. Glennon (1978). "Accident and Speed Studies in Construction Zones." *Transportation Research Record 693.* Washington, DC: Transportation Research Board, 25-32

Ha, Tae-Jun and Zoltan A. Nemeth (1995). "Detailed Study of Accident Experience in Construction and Maintenance Zones." *Transportation Research Record 1509.* Washington, DC: Transportation Research Board, 38-45.

Hall, J. W. and V. M. Lorentz (1989). "Characteristics of Construction Zone Accidents." *Transportation Research Record 1230.* Washington, DC: Transportation Research Board, 20-27.

Hargroves, Bradley T., and Michael R. Martin. *Vehicle Accidents in Workzones.* Charlottesville, VA: University of Virginia, December 1980.

Hauer, Ezra and A. S. Hakkert (1988). "Extent and Some Implications of Incomplete Accident Reporting." *Transportation Research Record 1185.* Washington, DC: Transportation Research Board, 1-10

Homburger W. S. *Traffic Control in Construction Zones with Nighttime Activities.* Report UCB-ITS-RR-89-10, Berkeley, CA: Institute of Transportation Studies, University of California, 1989.

Ibrahim, K. and D. T. Silcock (September 1992). "The Accuracy of Accident Data." *Traffic Engineering and Control* 33, No. 9, 492-497.

"Illinois Compiled Statutes, Chapter 625 [ILCS 625]." *Illinois Vehicle Code, 1996.* Springfield, IL: State of Illinois, 1996.

*Illinois Crash Facts and Statistics, 1994.* Springfield, IL: Illinois Department of Transportation, 1996.

Kacir K. C., and H. G. Hawkins (1993). "Traffic Control Guidelines For Urban Arterial Workzones." *Transportation Research Record 1409.* Washington, DC: Transportation Research Board, 23-31.

Kubala B. (1993). "Automatic Lane Neutralization Device (Nav) Trials on the A8 Motorway." *Proceedings of the First World Congress on Advanced Transport Telematics and Intelligent Vehicle Highway Systems.* vol. 4, Boston, MA: ERTICO. 2180-2183.

Kuemmel D. A. (1992). "Maximizing Legibility of Traffic Signs in Construction Workzones" *Transportation Research Record, 1352.* Washington, DC: Transportation Research Board, 25-34.

Lyles R. W. (1988). "Alternative Sign Sequences for Workzones on Rural Highways," *Review of Workzone Literature*, Pigman, J. G., and K. R. Agent, eds., Louisville, KY: University of Kentucky, College of Engineering.

Mace D., M. Finkle, and S. Pennak (1996). "Photometric Requirements for Arrow Panel Visibility" *Transportation Research Record 1553.* Washington, DC: Transportation Research Board, 66-72.

Marsella M., *Evaluation of Highway Advisory Radio (HAR) In a Construction Zone On I-80 Morris County, NJ.* Report 90-003-7050, Trenton, NJ: New Jersey Department of Transportation, 1989.

McCoy, Patrick T., James A. Bonneson, and James A. Kollbaum (1995). "Speed Reduction Effects of Speed Monitoring Displays with Radar in Workzones on Interstate Highways." *Transportation Research Record 1509.* Washington, DC: Transportation Research Board, 65-72

McCoy P. T., and D. J. Peterson (1988). "Safety Effects of Two-lane Two-way Segment Length Through Workzones on Normally Four-lane Divided Highways." *Transportation Research Record, 1163.* Washington, DC: Transportation Research Board, 15-21.

*Model Minimum Uniform Crash Coding.* Washington, DC: Federal Highway Administration, US Department of Transporttation, August 1998.

Nemeth, Zoltan A. *A Study of Accident Experience in Construction and Maintenance Zones.* Columbus, OH: Ohio State University, December 1990.

Nemeth Z. A., and T. Ha (1995). "Detailed Study of Accident Experience in Construction and Maintenance Zones" *Transportation Research Record 1509.* Washington, DC: Transportation Research Board, 38-45.

Nemeth, Zoltan A. and Donald J. Migletz (1978) "Accident Characteristics Before, During, and After Safety Upgrading Projects on Ohio's Rural Interstate System." *Transportation Research Record 672.* Washington, DC: Transportation Research Board, 19-24.

Nemeth Z. A., and A. Rathi (January 1983). " Freeway Workzone Accident Characteristics," *Transportation Quarterly* 37, No. 1, 145-159.

Noel, Errol C. (1992) " Practices and Needs in Workzone Pedestrian Safety", *Transportation Research Record 1352.* Washington, DC: Transportation Research Board, 17-24.

Noel, Errol C., Conrad L. Dudek, Olga J. Pendleton, and Ziad A. Sabra !989). "Speed Control Through Freeway Workzones: Techniques Evaluation." *Transportation Research Record 1163.* Washington, DC: Transportation Research Board, 31-42.

O'Day, James. *Accident Data Quality, National Cooperative Highway Research Program Synthesis of Highway Practice.* Washington, DC: Transportation Research Board, 1993.

Ogden M. A., and J. Mounce (1991). " Misunderstood Applications of Urban Workzone Traffic Control." *Transportation Research Record 1304.* Washington, D.C.: Transportation Research Board, 245-251.

Pal, R. and K. C. Sinha (1996). "Evaluation of Crossover and Partial Lane Closure Strategies for Interstate Workzones in Indiana." *Transportation Research Record 1529.* Washington, DC: Transportation Research Board, 10-18.

Pfefer, Ronald, Roy Lucke, and Richard Raub. *Economic Analysis of Highway Safety Data: Collection and Management of Highway Safety Data.* Evanston, IL: Northwestern University Traffic Institute, December 1993.

Pfefer, Ronald C., Richard A. Raub, and Roy E. Lucke. *Economic Analysis of Highway Safety Data.* DTFH61-91-C-00051, Evanston, IL: Northwestern University Traffic Institute, January 1996.

Pigman, Jerry G. and Kenneth R. Agent (1990). "Highway Accidents in Construction and Maintenance Workzones." *Transportation Research Record 1270.* Washington, DC: Transportation Research Board, 12-21

Rathbone D. B. (1991). "Safety and Capacity Benefits Associated with the Use of a Moveable Concrete Barrier." *Compendium of Technical Papers, ITE 61st,* Washington DC: Institute of Transportation Engineers, 84-88 .

Raub, Richard A., Roy E. Lucke, Joseph L. Schofer, Charles H. McLean, and Erin Bard. *Managing Incidents on Arterial Roadways A Final Report.* Evanston, IL: Northwestern University Traffic Institute, February 1996.

Rouphail N. M., Z. S. Yang, and J. Fazio (1988). "A Comparative Study of Short and Long Term Urban Freeway Workzones." *Transportation Research Record 1163.* Washington, DC: Transportation Research Board, 4-14.

Rouphail N. M., A. Sadegh, and A. E. A., Radwan (1988). "ARTWORK: A Simulation Model of Urban Arterial Workzones." *Transportation Research Record 1163.* Washington, DC: Transportation Research Board, 1-3.

Shepard F. D. (1990). " Improving Work-Zone Delineation on Limited Access Highways." *Transportation Research Record 1254.* Washington, DC: Transportation Research Board, 36-43.

Shibuya S., *et al.* (1996). "Traffic Control at Flagger-operated Workzones on Two-lane Roads" *Transportation Research Record 1529.* Washington, DC: Transportation Research Board, 3-9 .

Sorock, Gary S., Thomas A. Ranney, and Mark R. Lehto. "Motor Vehicle Crashes in Roadway Construction Zones: an Analysis Using Narrative Text From Insurance Claims." *Accident Analysis and Prevention* 28, no. 1 (January 1996): 131-38.

Ugwoaba G. U. *Evaluation of Delineation Systems for Temporary Traffic Barriers in Workzones.* Olympia, WA: Washington State Department of Transportation, 1989.

Ullman, Gerald L. (1996) "Queuing and Natural Diversion at Short-Term Freeway Workzone Lane Closures." *Transportation Research Record 1529.* Washington, DC: Transportation Research Board, 19-26.

Ullman G. L., R. A. Krammes, and C. L. Dudek. *Synthesis of Traffic Management Techniques for Major Urban Freeway Reconstruction* College Station, TX: Texas Transportation Institute, 1989.

Ullman G. L., and S. Z. Levine (1987). "An Evaluation of Portable Traffic Signals at Workzones" *Transportation Research Record 1148.* Washington, DC: Transportation Research Board, 30-33.

Ullman G. L., S. Z. Levine, and S. C. Booker (1987). "Supplemental Devices to Enhance Flagger Safety." *Transportation Research Record 1148.* Washington DC: Transportation Research Board, 34-37.

Wang, Jun, Warren E. Hughes, Forrest M. Council, and Jeffery F. Paniati (1996). "Investigation of Highway Workzone Crashes: What We Known and What We Don't Know." *Transportation Research Record Transportation Research Record 1592.* Washington, DC: Transportation Research Board, 54-64.

"Which Work-Zone Safety Devices, Methods Work Best?" *Better Roads*, 64, No.8, (1994), 33-34.

# Appendix A

## Cross Tabulation of Workzone Crash Characteristics

## Codes Used for Cross Tabulations

COLL - Type of First Crash

1 Pedestrian
2 Pedalcyclist
3 Train
4 Animal
5 Overturned
6 Fixed object
7 Other object
8 Other non collision
9 Parked motor vehicle
10 Turning
11 Rear end
12 Sideswipe same direction
13 Sideswipe opposite direction
14 Head on
15 Angle

RDEF - Road Defects

1 No defects
2 Construction zone
3 Maintenance zone
4 Utility zone
5 Work zone - unknown
6 Shoulders
7 Rut, loose dirt
8 Worn surface
9 Debris on roadway
10 Other
99 Unknown

RSUR - Roadway Surface Condition

1 Dy
2 Wet
3 Snow or slush
4 Ice
5 Sand, mud, dirt
6 Other
9 Unknown

TRFD - Traffic Control Device

1 No controls
2 Stop sign/flasher
3 Traffic signal
4 Yield
5 Police/flagman
6 RR crossing gate
7 Other RR crossing
8 School zone
9 No passing
10 Other regulatory sign
11 Other warning sign
12 Lane use marking
13 Other
99 Unknown

TRFW - Trafficway Description

Two-way
- 1 Not divided
- 2 Divided, no median barrier
- 3 Divided with median barrier
- 4 Center turn lane

5 One-way or ramp
6 Alley or driveway
7 Parking lot
8 Other
9 Unknown

WEAT - Weather Condition

1 Clear
2 Rain
3 Snow
4 Fog/smoke/haze
5 Sleet/hail
6 Severe cross wind
7 Other
9 Unknown

| | NUMBER OF VEHICLES | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| | N | N | N | N | N |
| TYPE OF COLLISION | | | | | |
| 2 | 139.00 | 6.00 | . | . | . |
| 3 | 129.00 | 5.00 | 1.00 | . | . |
| 4 | 3.00 | . | . | . | . |
| 5 | 53.00 | 1.00 | . | . | . |
| 6 | 148.00 | 6.00 | 1.00 | . | . |
| 7 | 907.00 | 57.00 | 7.00 | 4.00 | . |
| 8 | 305.00 | 52.00 | 4.00 | . | . |
| 9 | 644.00 | 242.00 | 30.00 | 5.00 | . |
| 10 | 3.00 | 445.00 | 31.00 | 7.00 | 2.00 |
| 12 | 6.00 | 3429.00 | 898.00 | 212.00 | 35.00 |
| 13 | 3.00 | 118.00 | 12.00 | 3.00 | 3.00 |
| 14 | 6.00 | 1168.00 | 44.00 | 9.00 | 2.00 |
| 15 | 1.00 | 166.00 | 14.00 | 2.00 | 1.00 |
| 16 | 11.00 | 1075.00 | 75.00 | 11.00 | 2.00 |
| 17 | 17.00 | 1555.00 | 87.00 | 15.00 | 2.00 |
| 18 | 352.00 | 1253.00 | 81.00 | 33.00 | 2.00 |
| ALL | 2727.00 | 9578.00 | 1285.00 | 301.00 | 49.00 |

(CONTINUED)

| | NUMBER OF VEHICLES | |
|---|---|---|
| | 6 | 7 |
| | N | N |
| TYPE OF COLLISION | | |
| 2 | . | . |
| 3 | . | . |
| 4 | . | . |
| 5 | . | . |
| 6 | . | . |
| 7 | . | . |
| 8 | . | . |
| 9 | 1.00 | . |
| 10 | . | . |
| 12 | 8.00 | 2.00 |
| 13 | . | . |
| 14 | . | 2.00 |
| 15 | . | . |
| 16 | . | . |
| 17 | . | . |
| 18 | 2.00 | . |
| ALL | 11.00 | 4.00 |

| | ACCIDENT SEVERITY | | |
|---|---|---|---|
| | Fatal | Injury | PDO |
| | N | N | N |
| TYPE OF COLLISION | | | |
| 2 | 6.00 | 95.00 | 44.00 |
| 3 | 3.00 | 119.00 | 13.00 |
| 4 | . | 2.00 | 1.00 |
| 5 | . | 47.00 | 7.00 |
| 6 | . | 9.00 | 146.00 |
| 7 | 9.00 | 382.00 | 584.00 |
| 8 | 3.00 | 82.00 | 276.00 |
| 9 | . | 215.00 | 707.00 |
| 10 | . | 55.00 | 433.00 |
| 12 | 8.00 | 1888.00 | 2694.00 |
| 13 | 7.00 | 72.00 | 60.00 |
| 14 | . | 224.00 | 1007.00 |
| 15 | 4.00 | 47.00 | 133.00 |
| 16 | 7.00 | 397.00 | 770.00 |
| 17 | 3.00 | 552.00 | 1121.00 |
| 18 | 2.00 | 371.00 | 1350.00 |
| ALL | 52.00 | 4557.00 | 9346.00 |

| | TRAFFICWAY CLASS | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| | N | N | N | N | N |
| TYPE OF COLLISION | | | | | |
| 2 | 2.00 | 23.00 | 28.00 | 12.00 | 3.00 |
| 3 | 2.00 | 1.00 | 6.00 | . | 1.00 |
| 4 | . | . | . | . | . |
| 5 | . | . | 1.00 | . | . |
| 6 | . | 17.00 | 52.00 | 8.00 | 3.00 |
| 7 | 12.00 | 76.00 | 108.00 | 48.00 | 25.00 |
| 8 | 3.00 | 40.00 | 18.00 | 10.00 | 22.00 |
| 9 | 6.00 | 56.00 | 60.00 | 35.00 | 24.00 |
| 10 | 1.00 | 7.00 | 15.00 | 18.00 | 2.00 |
| 12 | 17.00 | 170.00 | 329.00 | 30.00 | 89.00 |
| 13 | 1.00 | 1.00 | 8.00 | 8.00 | . |
| 14 | 2.00 | 68.00 | 32.00 | 1.00 | 28.00 |
| 15 | 1.00 | 3.00 | 31.00 | 2.00 | . |
| 16 | 7.00 | 12.00 | 72.00 | 26.00 | 5.00 |
| 17 | 13.00 | 5.00 | 77.00 | 26.00 | 2.00 |
| 18 | 1.00 | 9.00 | 12.00 | 3.00 | 4.00 |
| ALL | 68.00 | 488.00 | 849.00 | 227.00 | 208.00 |

(CONTINUED)

| | TRAFFICWAY CLASS | | | | |
|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 |
| | N | N | N | N | N |
| TYPE OF COLLISION | | | | | |
| 2 | 21.00 | 24.00 | 5.00 | 19.00 | 8.00 |
| 3 | 9.00 | 35.00 | 7.00 | 70.00 | 4.00 |
| 4 | . | 1.00 | . | 2.00 | . |
| 5 | . | 18.00 | 5.00 | 30.00 | . |
| 6 | 11.00 | 35.00 | 5.00 | 20.00 | 4.00 |
| 7 | 185.00 | 156.00 | 36.00 | 224.00 | 105.00 |
| 8 | 47.00 | 85.00 | 14.00 | 100.00 | 22.00 |
| 9 | 72.00 | 244.00 | 45.00 | 306.00 | 74.00 |
| 10 | 23.00 | 29.00 | 13.00 | 373.00 | 7.00 |
| 12 | 907.00 | 1609.00 | 249.00 | 908.00 | 282.00 |
| 13 | 6.00 | 39.00 | 11.00 | 64.00 | 1.00 |
| 14 | 265.00 | 319.00 | 55.00 | 350.00 | 111.00 |
| 15 | 5.00 | 60.00 | 12.00 | 68.00 | 2.00 |
| 16 | 38.00 | 389.00 | 88.00 | 523.00 | 14.00 |
| 17 | 13.00 | 759.00 | 149.00 | 631.00 | 1.00 |
| 18 | 24.00 | 26.00 | 9.00 | 1622.00 | 13.00 |
| ALL | 1626.00 | 3828.00 | 703.00 | 5310.00 | 648.00 |

| | WEATHER NEW | | | | |
|---|---|---|---|---|---|
| | Blank | Clear | Rain | Snow | Fog/smoke |
| | N | N | N | N | N |
| TYPE OF COLLISION | | | | | |
| 2 | . | 124.00 | 17.00 | . | 2.00 |
| 3 | . | 122.00 | 11.00 | 1.00 | . |
| 4 | . | 3.00 | . | . | . |
| 5 | 1.00 | 49.00 | 3.00 | . | . |
| 6 | 2.00 | 135.00 | 16.00 | 1.00 | 1.00 |
| 7 | 4.00 | 767.00 | 154.00 | 22.00 | 17.00 |
| 8 | 4.00 | 306.00 | 41.00 | 5.00 | 3.00 |
| 9 | 11.00 | 743.00 | 127.00 | 22.00 | 9.00 |
| 10 | 10.00 | 410.00 | 43.00 | 12.00 | 1.00 |
| 12 | 14.00 | 3837.00 | 616.00 | 65.00 | 30.00 |
| 13 | 1.00 | 110.00 | 23.00 | 3.00 | 1.00 |
| 14 | 4.00 | 1074.00 | 111.00 | 16.00 | 6.00 |
| 15 | . | 144.00 | 28.00 | 7.00 | 2.00 |
| 16 | 4.00 | 970.00 | 146.00 | 26.00 | 8.00 |
| 17 | 7.00 | 1409.00 | 217.00 | 18.00 | 7.00 |
| 18 | 2.00 | 1390.00 | 203.00 | 52.00 | 10.00 |
| ALL | 64.00 | 11593.00 | 1756.00 | 250.00 | 97.00 |

(CONTINUED)

| | WEATHER NEW | | |
|---|---|---|---|
| | Sleet/hail | Cross wind | Unknown |
| | N | N | N |
| TYPE OF COLLISION | | | |
| 2 | 1.00 | . | 1.00 |
| 3 | . | . | 1.00 |
| 4 | . | . | . |
| 5 | . | . | 1.00 |
| 6 | . | . | . |
| 7 | 4.00 | . | 7.00 |
| 8 | 1.00 | . | 1.00 |
| 9 | 2.00 | . | 8.00 |
| 10 | 1.00 | . | 11.00 |
| 12 | 4.00 | . | 24.00 |
| 13 | . | . | 1.00 |
| 14 | 4.00 | . | 16.00 |
| 15 | 1.00 | . | 2.00 |
| 16 | 1.00 | 3.00 | 16.00 |
| 17 | 7.00 | 1.00 | 10.00 |
| 18 | 10.00 | . | 56.00 |
| ALL | 36.00 | 4.00 | 155.00 |

| | LIGHT CONDITION | | | | |
|---|---|---|---|---|---|
| | Blank | Daylight | Dawn | Dusk | Darkness |
| | N | N | N | N | N |
| TYPE OF COLLISION | | | | | |
| 2 | . | 69.00 | 2.00 | 3.00 | 51.00 |
| 3 | . | 100.00 | 2.00 | 4.00 | 10.00 |
| 4 | . | 1.00 | . | . | 1.00 |
| 5 | . | 40.00 | . | 4.00 | 5.00 |
| 6 | . | 20.00 | 9.00 | 9.00 | 106.00 |
| 7 | 2.00 | 446.00 | 22.00 | 19.00 | 241.00 |
| 8 | 1.00 | 186.00 | 9.00 | 3.00 | 92.00 |
| 9 | 3.00 | 504.00 | 18.00 | 16.00 | 193.00 |
| 10 | 12.00 | 336.00 | 6.00 | 6.00 | 46.00 |
| 12 | 5.00 | 3680.00 | 53.00 | 80.00 | 228.00 |
| 13 | 1.00 | 87.00 | . | 3.00 | 17.00 |
| 14 | 1.00 | 945.00 | 17.00 | 22.00 | 75.00 |
| 15 | 1.00 | 119.00 | 1.00 | 4.00 | 35.00 |
| 16 | 5.00 | 920.00 | 17.00 | 28.00 | 74.00 |
| 17 | 1.00 | 1281.00 | 20.00 | 50.00 | 116.00 |
| 18 | 50.00 | 1079.00 | 25.00 | 54.00 | 88.00 |
| ALL | 82.00 | 9813.00 | 201.00 | 305.00 | 1378.00 |

(CONTINUED)

| | LIGHT CONDITION |
|---|---|
| | Dark - lighted |
| | N |
| TYPE OF COLLISION | |
| 2 | 20.00 |
| 3 | 19.00 |
| 4 | 1.00 |
| 5 | 5.00 |
| 6 | 11.00 |
| 7 | 245.00 |
| 8 | 70.00 |
| 9 | 188.00 |
| 10 | 82.00 |
| 12 | 544.00 |
| 13 | 31.00 |
| 14 | 171.00 |
| 15 | 24.00 |
| 16 | 130.00 |
| 17 | 208.00 |
| 18 | 427.00 |
| ALL | 2176.00 |

| | RDWY SURFACE NEW | | | | |
|---|---|---|---|---|---|
| | Blank | Dry | Wet | Snow/slush | Ice |
| | N | N | N | N | N |
| TYPE OF COLLISION | | | | | |
| 2 | 2.00 | 100.00 | 27.00 | 1.00 | 3.00 |
| 3 | 8.00 | 106.00 | 12.00 | 1.00 | . |
| 4 | . | 2.00 | 1.00 | . | . |
| 5 | 3.00 | 41.00 | 5.00 | . | . |
| 6 | 7.00 | 124.00 | 22.00 | . | 1.00 |
| 7 | 31.00 | 650.00 | 203.00 | 21.00 | 23.00 |
| 8 | 9.00 | 275.00 | 47.00 | 5.00 | 2.00 |
| 9 | 60.00 | 605.00 | 155.00 | 21.00 | 13.00 |
| 10 | 28.00 | 333.00 | 50.00 | 11.00 | 5.00 |
| 12 | 175.00 | 3460.00 | 754.00 | 40.00 | 20.00 |
| 13 | 3.00 | 95.00 | 26.00 | 3.00 | 3.00 |
| 14 | 35.00 | 1007.00 | 144.00 | 12.00 | 2.00 |
| 15 | 9.00 | 128.00 | 30.00 | 6.00 | 2.00 |
| 16 | 59.00 | 835.00 | 190.00 | 18.00 | 11.00 |
| 17 | 77.00 | 1225.00 | 274.00 | 14.00 | 8.00 |
| 18 | 8.00 | 1186.00 | 272.00 | 46.00 | 8.00 |
| ALL | 514.00 | 10172.00 | 2212.00 | 199.00 | 101.00 |

(CONTINUED)

| | RDWY SURFACE NEW | |
|---|---|---|
| | Sand/dirt | Unknown |
| | N | N |
| TYPE OF COLLISION | | |
| 2 | 7.00 | 5.00 |
| 3 | 5.00 | 3.00 |
| 4 | . | . |
| 5 | 4.00 | 1.00 |
| 6 | . | 1.00 |
| 7 | 29.00 | 18.00 |
| 8 | 10.00 | 13.00 |
| 9 | 33.00 | 35.00 |
| 10 | 36.00 | 25.00 |
| 12 | 65.00 | 76.00 |
| 13 | 5.00 | 4.00 |
| 14 | 9.00 | 22.00 |
| 15 | 4.00 | 5.00 |
| 16 | 29.00 | 32.00 |
| 17 | 30.00 | 48.00 |
| 18 | 41.00 | 162.00 |
| ALL | 307.00 | 450.00 |

| | TRAFFIC CONTROL CONDITION | | | | |
|---|---|---|---|---|---|
| | Blank | No Controls | Not functioning | Improper function | Proper function |
| | N | N | N | N | N |
| TYPE OF COLLISION | | | | | |
| 2 | 6.00 | 67.00 | 1.00 | 4.00 | 63.00 |
| 3 | 28.00 | 47.00 | 1.00 | . | 51.00 |
| 4 | . | . | 1.00 | . | 2.00 |
| 5 | 5.00 | 24.00 | . | 3.00 | 21.00 |
| 6 | 5.00 | 111.00 | . | . | 35.00 |
| 7 | 62.00 | 436.00 | 7.00 | 21.00 | 429.00 |
| 8 | 33.00 | 151.00 | 7.00 | 14.00 | 149.00 |
| 9 | 61.00 | 405.00 | 6.00 | 26.00 | 378.00 |
| 10 | 168.00 | 250.00 | . | 3.00 | 60.00 |
| 12 | 290.00 | 1852.00 | 23.00 | 106.00 | 2210.00 |
| 13 | 24.00 | 65.00 | . | 5.00 | 43.00 |
| 14 | 169.00 | 491.00 | 5.00 | 30.00 | 506.00 |
| 15 | 28.00 | 86.00 | 1.00 | 2.00 | 59.00 |
| 16 | 189.00 | 287.00 | 5.00 | 37.00 | 637.00 |
| 17 | 207.00 | 473.00 | 8.00 | 38.00 | 934.00 |
| 18 | 1599.00 | 45.00 | . | 4.00 | 69.00 |
| ALL | 2874.00 | 4790.00 | 65.00 | 293.00 | 5646.00 |

(CONTINUED)

| | TRAFFIC CONTROL CONDITION | | |
|---|---|---|---|
| | Worn | Missing | Unknown |
| | N | N | N |
| TYPE OF COLLISION | | | |
| 2 | . | 1.00 | 3.00 |
| 3 | 4.00 | . | 4.00 |
| 4 | . | . | . |
| 5 | . | . | 1.00 |
| 6 | 2.00 | . | 2.00 |
| 7 | 2.00 | 3.00 | 15.00 |
| 8 | 2.00 | 1.00 | 4.00 |
| 9 | 13.00 | 8.00 | 25.00 |
| 10 | 3.00 | . | 4.00 |
| 12 | 20.00 | 2.00 | 87.00 |
| 13 | 1.00 | . | 1.00 |
| 14 | 6.00 | 2.00 | 22.00 |
| 15 | 2.00 | . | 6.00 |
| 16 | 3.00 | 2.00 | 14.00 |
| 17 | 3.00 | 1.00 | 12.00 |
| 18 | . | . | 6.00 |
| ALL | 61.00 | 20.00 | 206.00 |

| | TRAF CNTL TYPE | | | | |
|---|---|---|---|---|---|
| | 00 | 01 | 02 | 03 | 04 |
| | N | N | N | N | N |
| TYPE OF COLLISION | | | | | |
| 2 | . | 63.00 | 2.00 | 6.00 | 1.00 |
| 3 | . | 45.00 | 5.00 | 19.00 | . |
| 4 | . | . | . | . | . |
| 5 | . | 25.00 | 9.00 | 12.00 | . |
| 6 | . | 115.00 | . | 2.00 | . |
| 7 | 1.00 | 431.00 | 38.00 | 58.00 | 7.00 |
| 8 | . | 146.00 | 4.00 | 13.00 | 4.00 |
| 9 | . | 397.00 | 45.00 | 84.00 | 11.00 |
| 10 | 1.00 | 248.00 | 9.00 | 10.00 | . |
| 12 | 2.00 | 1792.00 | 147.00 | 953.00 | 81.00 |
| 13 | . | 64.00 | 6.00 | 22.00 | . |
| 14 | . | 472.00 | 18.00 | 151.00 | 35.00 |
| 15 | . | 83.00 | 13.00 | 19.00 | 2.00 |
| 16 | . | 283.00 | 319.00 | 242.00 | 11.00 |
| 17 | . | 463.00 | 271.00 | 626.00 | 7.00 |
| 18 | . | 42.00 | 2.00 | 7.00 | . |
| ALL | 4.00 | 4669.00 | 888.00 | 2224.00 | 159.00 |

(CONTINUED)

| | TRAF CNTL TYPE | | | | |
|---|---|---|---|---|---|
| | 05 | 06 | 07 | 08 | 09 |
| | N | N | N | N | N |
| TYPE OF COLLISION | | | | | |
| 2 | 1.00 | . | . | . | 6.00 |
| 3 | 23.00 | . | . | 1.00 | . |
| 4 | . | 1.00 | 2.00 | . | . |
| 5 | 1.00 | . | . | . | . |
| 6 | . | . | . | . | 10.00 |
| 7 | 11.00 | 2.00 | 3.00 | . | 13.00 |
| 8 | 11.00 | 1.00 | . | . | 2.00 |
| 9 | 16.00 | 1.00 | . | . | 20.00 |
| 10 | 15.00 | . | . | . | 1.00 |
| 12 | 274.00 | 7.00 | 5.00 | . | 60.00 |
| 13 | 3.00 | . | . | . | 3.00 |
| 14 | 22.00 | . | . | . | 8.00 |
| 15 | 3.00 | . | . | . | 12.00 |
| 16 | 20.00 | 2.00 | 1.00 | 2.00 | 15.00 |
| 17 | 13.00 | . | . | . | 16.00 |
| 18 | 3.00 | . | . | . | 1.00 |
| ALL | 416.00 | 14.00 | 11.00 | 3.00 | 167.00 |

(CONTINUED)

| | TRAF CNTL TYPE | | | |
|---|---|---|---|---|
| | 10 | 11 | 12 | 99 |
| | N | N | N | N |
| TYPE OF COLLISION | | | | |
| 2 | 2.00 | 30.00 | 14.00 | 20.00 |
| 3 | 2.00 | 8.00 | 3.00 | 29.00 |
| 4 | . | . | . | . |
| 5 | . | 2.00 | 1.00 | 4.00 |
| 6 | 3.00 | 6.00 | 9.00 | 10.00 |
| 7 | 21.00 | 188.00 | 74.00 | 128.00 |
| 8 | 13.00 | 67.00 | 24.00 | 76.00 |
| 9 | 30.00 | 137.00 | 65.00 | 116.00 |
| 10 | 4.00 | 18.00 | 10.00 | 172.00 |
| 12 | 64.00 | 449.00 | 267.00 | 489.00 |
| 13 | 1.00 | 10.00 | 5.00 | 25.00 |
| 14 | 29.00 | 135.00 | 119.00 | 242.00 |
| 15 | 1.00 | 10.00 | 11.00 | 30.00 |
| 16 | 6.00 | 34.00 | 32.00 | 207.00 |
| 17 | 6.00 | 27.00 | 27.00 | 220.00 |
| 18 | 5.00 | 34.00 | 16.00 | 1613.00 |
| ALL | 187.00 | 1155.00 | 677.00 | 3381.00 |

| | NUMBER OF VEHICLES | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| | N | N | N | N | N |
| ACCIDENT SEVERITY | | | | | |
| Fatal | 16.00 | 27.00 | 5.00 | 2.00 | 1.00 |
| Injury | 985.00 | 2714.00 | 657.00 | 159.00 | 32.00 |
| PDO | 1726.00 | 6837.00 | 623.00 | 140.00 | 16.00 |
| ALL | 2727.00 | 9578.00 | 1285.00 | 301.00 | 49.00 |

(CONTINUED)

| | NUMBER OF VEHICLES | |
|---|---|---|
| | 6 | 7 |
| | N | N |
| ACCIDENT SEVERITY | | |
| Fatal | . | 1.00 |
| Injury | 7.00 | 3.00 |
| PDO | 4.00 | . |
| ALL | 11.00 | 4.00 |

| | TRAFFICWAY CLASS | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| | N | N | N | N | N |
| ACCIDENT SEVERITY | | | | | |
| Fatal | 1.00 | 3.00 | 11.00 | 3.00 | 1.00 |
| Injury | 28.00 | 175.00 | 342.00 | 91.00 | 93.00 |
| PDO | 39.00 | 310.00 | 496.00 | 133.00 | 114.00 |
| ALL | 68.00 | 488.00 | 849.00 | 227.00 | 208.00 |

(CONTINUED)

| | TRAFFICWAY CLASS | | | | |
|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 |
| | N | N | N | N | N |
| ACCIDENT SEVERITY | | | | | |
| Fatal | 8.00 | 16.00 | 1.00 | 7.00 | 1.00 |
| Injury | 715.00 | 1341.00 | 245.00 | 1262.00 | 265.00 |
| PDO | 903.00 | 2471.00 | 457.00 | 4041.00 | 382.00 |
| ALL | 1626.00 | 3828.00 | 703.00 | 5310.00 | 648.00 |

| | WEATHER NEW | | | | |
|---|---|---|---|---|---|
| | Blank | Clear | Rain | Snow | Fog/smoke |
| | N | N | N | N | N |
| ACCIDENT SEVERITY | | | | | |
| Fatal | . | 49.00 | 3.00 | . | . |
| Injury | 18.00 | 3828.00 | 575.00 | 52.00 | 39.00 |
| PDO | 46.00 | 7716.00 | 1178.00 | 198.00 | 58.00 |
| ALL | 64.00 | 11593.00 | 1756.00 | 250.00 | 97.00 |

(CONTINUED)

| | WEATHER NEW | | |
|---|---|---|---|
| | Sleet/hail | Cross wind | Unknown |
| | N | N | N |
| ACCIDENT SEVERITY | | | |
| Fatal | . | . | . |
| Injury | 7.00 | 3.00 | 35.00 |
| PDO | 29.00 | 1.00 | 120.00 |
| ALL | 36.00 | 4.00 | 155.00 |

| | LIGHT CONDITION | | | | |
|---|---|---|---|---|---|
| | Blank | Daylight | Dawn | Dusk | Darkness |
| | N | N | N | N | N |
| ACCIDENT SEVERITY | | | | | |
| Fatal | . | 23.00 | 2.00 | 1.00 | 16.00 |
| Injury | 5.00 | 3220.00 | 63.00 | 90.00 | 443.00 |
| PDO | 77.00 | 6570.00 | 136.00 | 214.00 | 919.00 |
| ALL | 82.00 | 9813.00 | 201.00 | 305.00 | 1378.00 |

(CONTINUED)

| | LIGHT CONDITION |
|---|---|
| | Dark - lighted |
| | N |
| ACCIDENT SEVERITY | |
| Fatal | 10.00 |
| Injury | 736.00 |
| PDO | 1430.00 |
| ALL | 2176.00 |

| | RDWY SURFACE NEW | | | | |
|---|---|---|---|---|---|
| | Blank | Dry | Wet | Snow/slush | Ice |
| | N | N | N | N | N |
| ACCIDENT SEVERITY | | | | | |
| Fatal | 3.00 | 42.00 | 6.00 | . | . |
| Injury | 151.00 | 3459.00 | 731.00 | 50.00 | 17.00 |
| PDO | 360.00 | 6671.00 | 1475.00 | 149.00 | 84.00 |
| ALL | 514.00 | 10172.00 | 2212.00 | 199.00 | 101.00 |

(CONTINUED)

| | RDWY SURFACE NEW | |
|---|---|---|
| | Sand/dirt | Unknown |
| | N | N |
| ACCIDENT SEVERITY | | |
| Fatal | . | 1.00 |
| Injury | 89.00 | 60.00 |
| PDO | 218.00 | 389.00 |
| ALL | 307.00 | 450.00 |

| | TRAFFIC CONTROL CONDITION | | | | |
|---|---|---|---|---|---|
| | Blank | No Controls | Not functioning | Improper function | Proper function |
| | N | N | N | N | N |
| ACCIDENT SEVERITY | | | | | |
| Fatal | . | 29.00 | . | . | 22.00 |
| Injury | 567.00 | 1662.00 | 14.00 | 99.00 | 2118.00 |
| PDO | 2307.00 | 3099.00 | 51.00 | 194.00 | 3506.00 |
| ALL | 2874.00 | 4790.00 | 65.00 | 293.00 | 5646.00 |

(CONTINUED)

| | TRAFFIC CONTROL CONDITION | | |
|---|---|---|---|
| | Worn | Missing | Unknown |
| | N | N | N |
| ACCIDENT SEVERITY | | | |
| Fatal | 1.00 | . | . |
| Injury | 21.00 | 7.00 | 69.00 |
| PDO | 39.00 | 13.00 | 137.00 |
| ALL | 61.00 | 20.00 | 206.00 |

| | TRAF CNTL TYPE | | | | |
|---|---|---|---|---|---|
| | 00 | 01 | 02 | 03 | 04 |
| | N | N | N | N | N |
| ACCIDENT SEVERITY | | | | | |
| Fatal | . | 27.00 | 2.00 | 5.00 | 1.00 |
| Injury | 2.00 | 1600.00 | 297.00 | 855.00 | 56.00 |
| PDO | 2.00 | 3042.00 | 589.00 | 1364.00 | 102.00 |
| ALL | 4.00 | 4669.00 | 888.00 | 2224.00 | 159.00 |

(CONTINUED)

| | TRAF CNTL TYPE | | | | |
|---|---|---|---|---|---|
| | 05 | 06 | 07 | 08 | 09 |
| | N | N | N | N | N |
| ACCIDENT SEVERITY | | | | | |
| Fatal | 1.00 | . | . | . | 2.00 |
| Injury | 172.00 | 5.00 | 5.00 | 2.00 | 61.00 |
| PDO | 243.00 | 9.00 | 6.00 | 1.00 | 104.00 |
| ALL | 416.00 | 14.00 | 11.00 | 3.00 | 167.00 |

(CONTINUED)

| | TRAF CNTL TYPE | | | |
|---|---|---|---|---|
| | 10 | 11 | 12 | 99 |
| | N | N | N | N |
| ACCIDENT SEVERITY | | | | |
| Fatal | 1.00 | 4.00 | 8.00 | 1.00 |
| Injury | 66.00 | 432.00 | 230.00 | 774.00 |
| PDO | 120.00 | 719.00 | 439.00 | 2606.00 |
| ALL | 187.00 | 1155.00 | 677.00 | 3381.00 |

| | TRAFFICWAY CLASS | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| | N | N | N | N | N |
| NUMBER OF VEHICLES | | | | | |
| 1 | 23.00 | 202.00 | 266.00 | 109.00 | 73.00 |
| 2 | 44.00 | 236.00 | 491.00 | 107.00 | 105.00 |
| 3 | 1.00 | 38.00 | 82.00 | 9.00 | 21.00 |
| 4 | . | 10.00 | 7.00 | 2.00 | 7.00 |
| 5 | . | 1.00 | 2.00 | . | . |
| 6 | . | . | . | . | 2.00 |
| 7 | . | 1.00 | 1.00 | . | . |
| ALL | 68.00 | 488.00 | 849.00 | 227.00 | 208.00 |

(CONTINUED)

| | TRAFFICWAY CLASS | | | | |
|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 |
| | N | N | N | N | N |
| NUMBER OF VEHICLES | | | | | |
| 1 | 323.00 | 510.00 | 106.00 | 921.00 | 194.00 |
| 2 | 981.00 | 2780.00 | 523.00 | 3978.00 | 333.00 |
| 3 | 244.00 | 428.00 | 63.00 | 313.00 | 86.00 |
| 4 | 64.00 | 83.00 | 9.00 | 90.00 | 29.00 |
| 5 | 11.00 | 23.00 | 2.00 | 6.00 | 4.00 |
| 6 | 1.00 | 4.00 | . | 2.00 | 2.00 |
| 7 | 2.00 | . | . | . | . |
| ALL | 1626.00 | 3828.00 | 703.00 | 5310.00 | 648.00 |

| | WEATHER NEW | | | | |
|---|---|---|---|---|---|
| | Blank | Clear | Rain | Snow | Fog/smoke |
| | N | N | N | N | N |
| NUMBER OF VEHICLES | | | | | |
| 1 | 18.00 | 2244.00 | 359.00 | 47.00 | 28.00 |
| 2 | 42.00 | 7977.00 | 1176.00 | 182.00 | 61.00 |
| 3 | 3.00 | 1072.00 | 167.00 | 16.00 | 6.00 |
| 4 | 1.00 | 251.00 | 42.00 | 2.00 | 2.00 |
| 5 | . | 38.00 | 8.00 | 3.00 | . |
| 6 | . | 8.00 | 3.00 | . | . |
| 7 | . | 3.00 | 1.00 | . | . |
| ALL | 64.00 | 11593.00 | 1756.00 | 250.00 | 97.00 |

(CONTINUED)

| | WEATHER NEW | | |
|---|---|---|---|
| | Sleet/hail | Cross wind | Unknown |
| | N | N | N |
| NUMBER OF VEHICLES | | | |
| 1 | 8.00 | . | 23.00 |
| 2 | 25.00 | 4.00 | 111.00 |
| 3 | 3.00 | . | 18.00 |
| 4 | . | . | 3.00 |
| 5 | . | . | . |
| 6 | . | . | . |
| 7 | . | . | . |
| ALL | 36.00 | 4.00 | 155.00 |

| | LIGHT CONDITION | | | | |
|---|---|---|---|---|---|
| | Blank | Daylight | Dawn | Dusk | Darkness |
| | N | N | N | N | N |
| NUMBER OF VEHICLES | | | | | |
| 1 | 12.00 | 1297.00 | 61.00 | 60.00 | 692.00 |
| 2 | 69.00 | 7241.00 | 118.00 | 208.00 | 615.00 |
| 3 | 1.00 | 987.00 | 17.00 | 29.00 | 58.00 |
| 4 | . | 240.00 | 4.00 | 6.00 | 9.00 |
| 5 | . | 38.00 | . | 2.00 | 2.00 |
| 6 | . | 7.00 | . | . | 2.00 |
| 7 | . | 3.00 | 1.00 | . | . |
| ALL | 82.00 | 9813.00 | 201.00 | 305.00 | 1378.00 |

(CONTINUED)

| | RDWY SURFACE NEW | |
|---|---|---|
| | Sand/dirt | Unknown |
| | N | N |
| NUMBER OF VEHICLES | | |
| 1 | 97.00 | 83.00 |
| 2 | 189.00 | 334.00 |
| 3 | 16.00 | 29.00 |
| 4 | 5.00 | 3.00 |
| 5 | . | 1.00 |
| 6 | . | . |
| 7 | . | . |
| ALL | 307.00 | 450.00 |

| | TRAFFIC CONTROL CONDITION | | | | |
|---|---|---|---|---|---|
| | Blank | No Controls | Not functioning | Improper function | Proper function |
| | N | N | N | N | N |
| NUMBER OF VEHICLES | | | | | |
| 1 | 411.00 | 1107.00 | 20.00 | 67.00 | 1041.00 |
| 2 | 2251.00 | 3038.00 | 39.00 | 196.00 | 3891.00 |
| 3 | 143.00 | 496.00 | 6.00 | 28.00 | 575.00 |
| 4 | 63.00 | 115.00 | . | 2.00 | 116.00 |
| 5 | 4.00 | 27.00 | . | . | 17.00 |
| 6 | 2.00 | 6.00 | . | . | 3.00 |
| 7 | . | 1.00 | . | . | 3.00 |
| ALL | 2874.00 | 4790.00 | 65.00 | 293.00 | 5646.00 |

(CONTINUED)

| | TRAFFIC CONTROL CONDITION | | |
|---|---|---|---|
| | Worn | Missing | Unknown |
| | N | N | N |
| NUMBER OF VEHICLES | | | |
| 1 | 18.00 | 13.00 | 50.00 |
| 2 | 37.00 | 7.00 | 119.00 |
| 3 | 6.00 | . | 31.00 |
| 4 | . | . | 5.00 |
| 5 | . | . | 1.00 |
| 6 | . | . | . |
| 7 | . | . | . |
| ALL | 61.00 | 20.00 | 206.00 |

| | TRAF CNTL TYPE | | | | |
|---|---|---|---|---|---|
| | 00 | 01 | 02 | 03 | 04 |
| | N | N | N | N | N |
| NUMBER OF VEHICLES | | | | | |
| 1 | 1.00 | 1087.00 | 90.00 | 156.00 | 17.00 |
| 2 | 2.00 | 2951.00 | 748.00 | 1780.00 | 129.00 |
| 3 | . | 484.00 | 45.00 | 253.00 | 12.00 |
| 4 | 1.00 | 113.00 | 4.00 | 29.00 | 1.00 |
| 5 | . | 27.00 | . | 6.00 | . |
| 6 | . | 6.00 | . | . | . |
| 7 | . | 1.00 | 1.00 | . | . |
| ALL | 4.00 | 4669.00 | 888.00 | 2224.00 | 159.00 |

(CONTINUED)

| | TRAF CNTL TYPE | | | | |
|---|---|---|---|---|---|
| | 05 | 06 | 07 | 08 | 09 |
| | N | N | N | N | N |
| NUMBER OF VEHICLES | | | | | |
| 1 | 54.00 | 4.00 | 4.00 | 1.00 | 43.00 |
| 2 | 281.00 | 7.00 | 6.00 | 2.00 | 106.00 |
| 3 | 65.00 | 2.00 | 1.00 | . | 14.00 |
| 4 | 13.00 | 1.00 | . | . | 3.00 |
| 5 | 2.00 | . | . | . | . |
| 6 | . | . | . | . | 1.00 |
| 7 | 1.00 | . | . | . | . |
| ALL | 416.00 | 14.00 | 11.00 | 3.00 | 167.00 |

(CONTINUED)

| | TRAF CNTL TYPE | | | |
|---|---|---|---|---|
| | 10 | 11 | 12 | 99 |
| | N | N | N | N |
| NUMBER OF VEHICLES | | | | |
| 1 | 65.00 | 431.00 | 182.00 | 592.00 |
| 2 | 100.00 | 568.00 | 400.00 | 2498.00 |
| 3 | 14.00 | 121.00 | 69.00 | 205.00 |
| 4 | 6.00 | 27.00 | 24.00 | 79.00 |
| 5 | 1.00 | 7.00 | 1.00 | 5.00 |
| 6 | 1.00 | . | 1.00 | 2.00 |
| 7 | . | 1.00 | . | . |
| ALL | 187.00 | 1155.00 | 677.00 | 3381.00 |

| | TRAFFICWAY CLASS | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| | N | N | N | N | N |
| WEATHER NEW | | | | | |
| Blank | . | 2.00 | 7.00 | . | . |
| Clear | 54.00 | 411.00 | 722.00 | 195.00 | 180.00 |
| Rain | 11.00 | 64.00 | 82.00 | 20.00 | 28.00 |
| Snow | 1.00 | 4.00 | 14.00 | 4.00 | . |
| Fog/smoke | 2.00 | 5.00 | 16.00 | 6.00 | . |
| Sleet/hail | . | 1.00 | 1.00 | 2.00 | . |
| Cross wind | . | . | 1.00 | . | . |
| Unknown | . | 1.00 | 6.00 | . | . |
| ALL | 68.00 | 488.00 | 849.00 | 227.00 | 208.00 |

(CONTINUED)

| | TRAFFICWAY CLASS | | | | |
|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 |
| | N | N | N | N | N |
| WEATHER NEW | | | | | |
| Blank | 7.00 | 19.00 | 2.00 | 27.00 | . |
| Clear | 1453.00 | 3154.00 | 561.00 | 4270.00 | 593.00 |
| Rain | 147.00 | 523.00 | 113.00 | 723.00 | 45.00 |
| Snow | 11.00 | 67.00 | 10.00 | 136.00 | 3.00 |
| Fog/smoke | 5.00 | 26.00 | 3.00 | 28.00 | 6.00 |
| Sleet/hail | 1.00 | 4.00 | 1.00 | 26.00 | . |
| Cross wind | . | 2.00 | . | 1.00 | . |
| Unknown | 2.00 | 33.00 | 13.00 | 99.00 | 1.00 |
| ALL | 1626.00 | 3828.00 | 703.00 | 5310.00 | 648.00 |

| | LIGHT CONDITION | | | | |
|---|---|---|---|---|---|
| | Blank | Daylight | Dawn | Dusk | Darkness |
| | N | N | N | N | N |
| WEATHER NEW | | | | | |
| Blank | 3.00 | 40.00 | 1.00 | . | 11.00 |
| Clear | 41.00 | 8431.00 | 146.00 | 229.00 | 1048.00 |
| Rain | 10.00 | 1049.00 | 39.00 | 65.00 | 235.00 |
| Snow | 2.00 | 134.00 | 4.00 | 6.00 | 42.00 |
| Fog/smoke | 1.00 | 50.00 | 8.00 | 1.00 | 26.00 |
| Sleet/hail | . | 17.00 | . | 1.00 | 6.00 |
| Cross wind | . | 2.00 | . | . | 1.00 |
| Unknown | 25.00 | 90.00 | 3.00 | 3.00 | 9.00 |
| ALL | 82.00 | 9813.00 | 201.00 | 305.00 | 1378.00 |

(CONTINUED)

| | LIGHT CONDITION |
|---|---|
| | Dark - lighted |
| | N |
| WEATHER NEW | |
| Blank | 9.00 |
| Clear | 1698.00 |
| Rain | 358.00 |
| Snow | 62.00 |
| Fog/smoke | 11.00 |
| Sleet/hail | 12.00 |
| Cross wind | 1.00 |
| Unknown | 25.00 |
| ALL | 2176.00 |

| | RDWY SURFACE NEW | | | | |
|---|---|---|---|---|---|
| | Blank | Dry | Wet | Snow/slush | Ice |
| | N | N | N | N | N |
| WEATHER NEW | | | | | |
| Blank | 19.00 | 35.00 | 4.00 | 1.00 | . |
| Clear | 402.00 | 9891.00 | 533.00 | 66.00 | 59.00 |
| Rain | 58.00 | 90.00 | 1544.00 | 7.00 | 5.00 |
| Snow | 22.00 | 15.00 | 53.00 | 120.00 | 25.00 |
| Fog/smoke | 2.00 | 52.00 | 35.00 | 1.00 | 2.00 |
| Sleet/hail | 3.00 | 12.00 | 7.00 | 3.00 | 7.00 |
| Cross wind | 1.00 | 3.00 | . | . | . |
| Unknown | 7.00 | 74.00 | 36.00 | 1.00 | 3.00 |
| ALL | 514.00 | 10172.00 | 2212.00 | 199.00 | 101.00 |

(CONTINUED)

| | RDWY SURFACE NEW | |
|---|---|---|
| | Sand/dirt | Unknown |
| | N | N |
| WEATHER NEW | | |
| Blank | 4.00 | 1.00 |
| Clear | 276.00 | 366.00 |
| Rain | 17.00 | 35.00 |
| Snow | 2.00 | 13.00 |
| Fog/smoke | 4.00 | 1.00 |
| Sleet/hail | 1.00 | 3.00 |
| Cross wind | . | . |
| Unknown | 3.00 | 31.00 |
| ALL | 307.00 | 450.00 |

| | TRAFFIC CONTROL CONDITION | | | | |
|---|---|---|---|---|---|
| | Blank | No Controls | Not functioning | Improper function | Proper function |
| | N | N | N | N | N |
| WEATHER NEW | | | | | |
| Blank | 22.00 | 30.00 | 1.00 | 1.00 | 8.00 |
| Clear | 2227.00 | 4042.00 | 57.00 | 239.00 | 4789.00 |
| Rain | 416.00 | 568.00 | 7.00 | 46.00 | 686.00 |
| Snow | 89.00 | 90.00 | . | 2.00 | 65.00 |
| Fog/smoke | 23.00 | 24.00 | . | 3.00 | 45.00 |
| Sleet/hail | 17.00 | 10.00 | . | . | 7.00 |
| Cross wind | . | 1.00 | . | . | 2.00 |
| Unknown | 80.00 | 25.00 | . | 2.00 | 44.00 |
| ALL | 2874.00 | 4790.00 | 65.00 | 293.00 | 5646.00 |

(CONTINUED)

| | TRAFFIC CONTROL CONDITION | | |
|---|---|---|---|
| | Worn | Missing | Unknown |
| | N | N | N |
| WEATHER NEW | | | |
| Blank | 1.00 | . | 1.00 |
| Clear | 51.00 | 16.00 | 172.00 |
| Rain | 5.00 | 3.00 | 25.00 |
| Snow | 1.00 | . | 3.00 |
| Fog/smoke | 1.00 | . | 1.00 |
| Sleet/hail | 1.00 | . | 1.00 |
| Cross wind | . | 1.00 | . |
| Unknown | 1.00 | . | 3.00 |
| ALL | 61.00 | 20.00 | 206.00 |

| | TRAF CNTL TYPE | | | | |
|---|---|---|---|---|---|
| | 00 | 01 | 02 | 03 | 04 |
| | N | N | N | N | N |
| WEATHER NEW | | | | | |
| Blank | 2.00 | 29.00 | 2.00 | 6.00 | . |
| Clear | 2.00 | 3928.00 | 741.00 | 1810.00 | 138.00 |
| Rain | . | 566.00 | 115.00 | 321.00 | 13.00 |
| Snow | . | 89.00 | 14.00 | 34.00 | 3.00 |
| Fog/smoke | . | 21.00 | 6.00 | 20.00 | 5.00 |
| Sleet/hail | . | 10.00 | 1.00 | 3.00 | . |
| Cross wind | . | 1.00 | 1.00 | 2.00 | . |
| Unknown | . | 25.00 | 8.00 | 28.00 | . |
| ALL | 4.00 | 4669.00 | 888.00 | 2224.00 | 159.00 |

(CONTINUED)

| | TRAF CNTL TYPE | | | | |
|---|---|---|---|---|---|
| | 05 | 06 | 07 | 08 | 09 |
| | N | N | N | N | N |
| WEATHER NEW | | | | | |
| Blank | . | . | . | . | 2.00 |
| Clear | 380.00 | 13.00 | 10.00 | 2.00 | 144.00 |
| Rain | 27.00 | 1.00 | 1.00 | 1.00 | 16.00 |
| Snow | 3.00 | . | . | . | 2.00 |
| Fog/smoke | 5.00 | . | . | . | . |
| Sleet/hail | . | . | . | . | 2.00 |
| Cross wind | . | . | . | . | . |
| Unknown | 1.00 | . | . | . | 1.00 |
| ALL | 416.00 | 14.00 | 11.00 | 3.00 | 167.00 |

(CONTINUED)

| | TRAF CNTL TYPE | | | |
|---|---|---|---|---|
| | 10 | 11 | 12 | 99 |
| | N | N | N | N |
| WEATHER NEW | | | | |
| Blank | . | 2.00 | 1.00 | 20.00 |
| Clear | 156.00 | 999.00 | 591.00 | 2679.00 |
| Rain | 30.00 | 130.00 | 65.00 | 470.00 |
| Snow | . | 8.00 | 6.00 | 91.00 |
| Fog/smoke | . | 9.00 | 10.00 | 21.00 |
| Sleet/hail | 1.00 | . | 1.00 | 18.00 |
| Cross wind | . | . | . | . |
| Unknown | . | 7.00 | 3.00 | 82.00 |
| ALL | 187.00 | 1155.00 | 677.00 | 3381.00 |

# Appendix B

## Crashes Occurring Along a Segment of IL 171
## Cook County, 1994

| OBS | MILEPOST | ACCDATE | HOUR | MIN | WORKZONE | ACC_SEV | NUMVEH | CASENO |
|---|---|---|---|---|---|---|---|---|
| 1 | 15.78 | 05/23/94 | 6 | 39 | YES | 3 | 4 | 230392 |
| 2 | 15.78 | 05/24/94 | 19 | 30 | NO | 3 | 1 | 232134 |
| 3 | 15.79 | 05/30/94 | 15 | 51 | NO | 3 | 2 | 240671 |
| 4 | 15.80 | 08/10/94 | 13 | 30 | NO | 3 | 2 | 355264 |
| 5 | 15.85 | 11/15/94 | 14 | 42 | NO | 3 | 1 | 517876 |
| 6 | 15.92 | 05/25/94 | 16 | 28 | NO | 3 | 2 | 233017 |
| 7 | 15.92 | 06/01/94 | 6 | 28 | YES | 3 | 2 | 243859 |
| 8 | 15.92 | 06/01/94 | 14 | 16 | NO | 3 | 2 | 243861 |
| 9 | 15.92 | 06/07/94 | 7 | 45 | NO | 2 | 2 | 253736 |
| 10 | 15.92 | 06/28/94 | 7 | 18 | NO | 3 | 2 | 288460 |
| 11 | 15.92 | 08/22/94 | 5 | 20 | YES | 3 | 2 | 375084 |
| 12 | 15.92 | 08/22/94 | 14 | 58 | NO | 3 | 2 | 375091 |
| 13 | 15.92 | 10/26/94 | 8 | 37 | NO | 3 | 3 | 480525 |
| 14 | 15.93 | 04/13/94 | 17 | 27 | NO | 3 | 2 | 167668 |
| 15 | 15.93 | 05/11/94 | 11 | 30 | YES | 3 | 3 | 210578 |
| 16 | 15.93 | 05/14/94 | 16 | 20 | YES | 3 | 1 | 215787 |
| 17 | 15.93 | 06/17/94 | 13 | 29 | YES | 2 | 3 | 271504 |
| 18 | 15.93 | 07/27/94 | 9 | 50 | NO | 3 | 2 | 333958 |
| 19 | 15.94 | 04/09/94 | 15 | 20 | NO | 3 | 2 | 161464 |
| 20 | 15.94 | 06/25/94 | 19 | 0 | NO | 3 | 2 | 280430 |
| 21 | 15.94 | 07/07/94 | 10 | 53 | NO | 3 | 2 | 302560 |
| 22 | 15.94 | 07/24/94 | 7 | 48 | NO | 2 | 2 | 329268 |
| 23 | 15.94 | 09/08/94 | 14 | 26 | NO | 3 | 2 | 401820 |
| 24 | 15.97 | 05/12/94 | 18 | 10 | YES | 3 | 2 | 212442 |
| 25 | 16.18 | 08/14/94 | 12 | 30 | NO | 3 | 2 | 362278 |
| 26 | 16.19 | 09/05/94 | 11 | 43 | NO | 3 | 2 | 396665 |
| 27 | 16.29 | 08/18/94 | 7 | 10 | NO | 3 | 1 | 425674 |
| 28 | 16.32 | 10/14/94 | 21 | 49 | YES | 2 | 3 | 460480 |
| 29 | 16.34 | 04/08/94 | 7 | 30 | NO | 3 | 1 | 159601 |
| 30 | 16.34 | 07/06/94 | 13 | 16 | NO | 3 | 2 | 300019 |
| 31 | 16.34 | 08/09/94 | 18 | 2 | NO | 2 | 2 | 353594 |
| 32 | 16.37 | 04/27/94 | 15 | 55 | YES | 2 | 3 | 187643 |
| 33 | 16.37 | 06/15/94 | 9 | 25 | NO | 3 | 2 | 267710 |
| 34 | 16.37 | 06/22/94 | 6 | 5 | YES | 3 | 2 | 279509 |
| 35 | 16.37 | 07/13/94 | 14 | 40 | NO | 3 | 2 | 311065 |
| 36 | 16.40 | 10/11/94 | 15 | 52 | YES | 2 | 3 | 455489 |
| 37 | 16.43 | 04/07/94 | 12 | 35 | YES | 2 | 2 | 158878 |
| 38 | 16.46 | 08/25/94 | 10 | 23 | NO | 2 | 3 | 379199 |
| 39 | 16.54 | 05/29/94 | 1 | 50 | YES | 3 | 1 | 240343 |
| 40 | 16.55 | 06/22/94 | 6 | 5 | YES | 3 | 1 | 279941 |
| 41 | 16.56 | 06/22/94 | 7 | 25 | YES | 2 | 2 | 279943 |
| 42 | 16.59 | 08/29/94 | 17 | 30 | NO | 3 | 3 | 386417 |
| 43 | 16.68 | 06/01/94 | 15 | 30 | NO | 3 | 2 | 243746 |
| 44 | 16.68 | 06/13/94 | 15 | 27 | YES | 2 | 2 | 264058 |
| 45 | 16.68 | 11/22/94 | 18 | 36 | NO | 3 | 3 | 528448 |
| 46 | 16.72 | 09/23/94 | 22 | 55 | YES | 2 | 1 | 425860 |
| 47 | 16.86 | 05/02/94 | 7 | 22 | YES | 3 | 3 | 196507 |
| 48 | 16.86 | 07/21/94 | 14 | 45 | NO | 3 | 2 | 324951 |

| OBS | MILEPOST | ACCDATE | HOUR | MIN | WORKZONE | ACC_SEV | NUMVEH | CASENO |
|---|---|---|---|---|---|---|---|---|
| 49 | 16.86 | 09/17/94 | 11 | 30 | NO | 3 | 2 | 415101 |
| 50 | 16.87 | 04/20/94 | 6 | 0 | NO | 3 | 2 | 178266 |
| 51 | 17.10 | 10/12/94 | 17 | 3 | NO | 3 | 2 | 457399 |
| 52 | 17.13 | 06/19/94 | 21 | 31 | NO | 3 | 2 | 274993 |
| 53 | 17.20 | 09/28/94 | 12 | 8 | NO | 2 | 2 | 433415 |
| 54 | 17.27 | 10/14/94 | 17 | 0 | NO | 3 | 1 | 459983 |
| 55 | 17.47 | 04/11/94 | 14 | 40 | NO | 3 | 3 | 163752 |
| 56 | 17.47 | 04/15/94 | 6 | 11 | YES | 3 | 3 | 170339 |
| 57 | 17.47 | 04/28/94 | 18 | 25 | YES | 2 | 2 | 190393 |
| 58 | 17.47 | 05/24/94 | 10 | 39 | YES | 3 | 2 | 231446 |
| 59 | 17.47 | 09/20/94 | 10 | 22 | NO | 2 | 2 | 420595 |
| 60 | 17.49 | 06/08/94 | 8 | 45 | YES | 3 | 2 | 254960 |
| 61 | 17.49 | 08/23/94 | 21 | 36 | NO | 3 | 2 | 376229 |

# Appendix C

## Supplemental Form Used for Reporting Workzone Crashes

# Supplemental Crash Reporting for Construction Zone Crashes

(To Be Completed for All Crashes Occurring
within a Construction Zone Reported On-Scene)

Date: ________________ Crash Report Nbr. ______________________

1. Did the construction zone (as defined on the reverse side) contribute to the crash (did it occur because the construction zone was there)?

   ❑ NO **Do not complete the form**

   ❑ *YES* ***Please continue with the form***

2. Based on the picture shown on the reverse side, where did the crash occur (check one)?

   ❑ Advance area
   ❑ Taper or crossover (to two-way traffic)
   ❑ Work area
   ❑ Exit

   Approximately how far from the point marking the *end of the taper (or crossover) and start of the work area* did the crash occur:

   _______ feet BEFORE or AFTER
   (circle one)

3. Which of the following elements related to the construction zone contributed to the crash? (check *all* that apply)

   ❑ Interference with the driving lane from *construction equipment or personnel.*
   ❑ Distraction resulting from activity in the work area.
   ❑ Obstructed view of traffic by vehicles, signs, or activity in the work area.
   ❑ Interference with the driving lane from *traffic control devices (cones, barriers, etc.).*
   ❑ Missing, improperly placed, or ambiguous striping, cones, barriers, or traffic control devices.
   ❑ Damaged pavement or unexpected changes in pavement levels.
   ❑ Narrow lanes
   ❑ Lack of adequate escape
   ❑ Other - please specify:

   ________________________________

4. What actions of motorists or vehicle, including the at-fault driver, contributed to the crash? (check all that apply)

   ❑ Stopping (stopped), sudden slowing, or driving at speed substantially below that of other traffic.
   ❑ Driving outside/straddling the marked lane.
   ❑ Unexpected lane change.
   ❑ Failure to yield from on-ramp or merging at taper.
   ❑ Driving *in excess* of the speed limit (indicate speed limit: _______ mph)
   ❑ Rapid acceleration, high speed, or lane changes in the exit zone.
   ❑ Following too closely.
   ❑ Driving too rapidly or improper passing prior to the taper.
   ❑ Distraction from within vehicle
   ❑ Alcohol, drugs, or asleep
   ❑ Vehicle defect
   ❑ Other, please specify:

   ________________________________

5. Was construction in progress at the time the crash occurred?

   ❑ YES ❑ NO

6. In your opinion, could changes have been made in design, marking, or other aspects of the construction zone that might have helped prevent the collision?

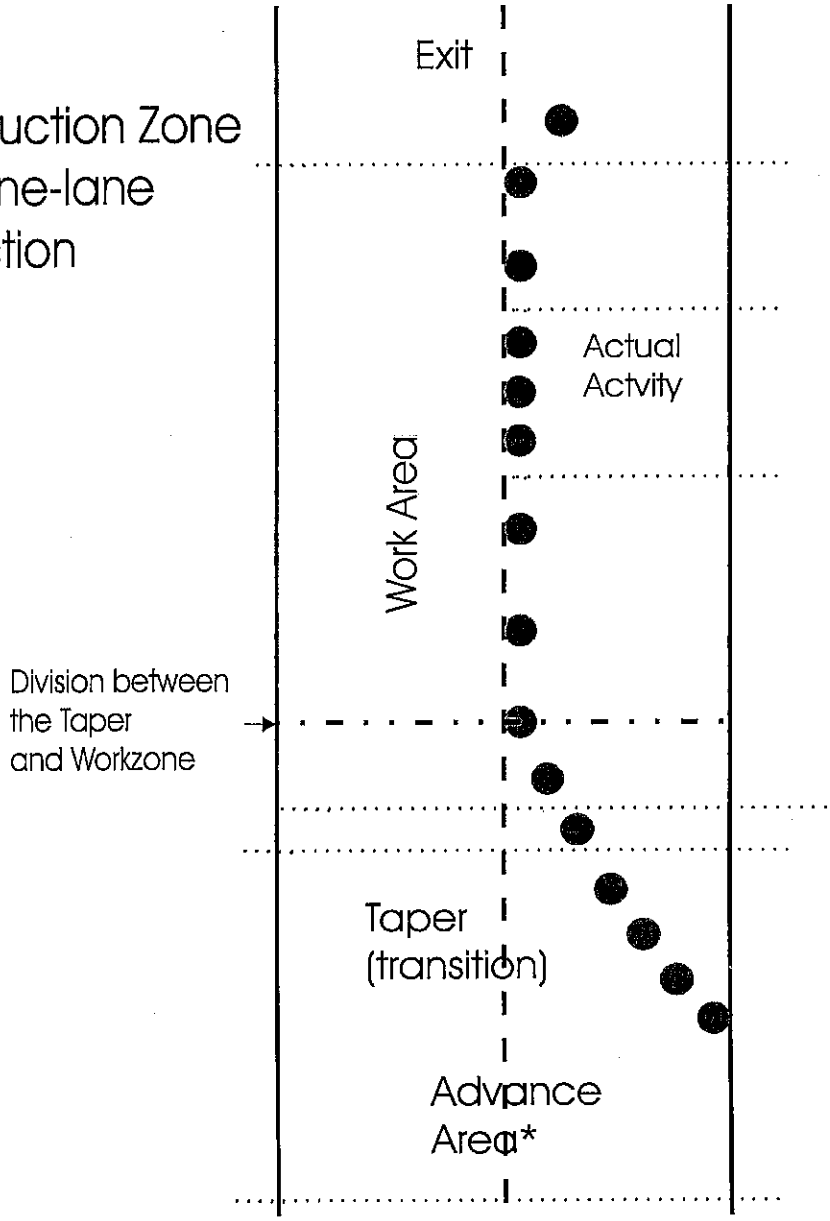
   ❑ YES ❑ NO

Specify:________________________________

________________________________________

________________________________________

# Construction Zone with One-lane Reduction




*Note: the advance area can vary in length depending upon traffic, but always should include the 1/2 mile preceding the work area.

Additional Notes:

## Supplemental Crash Reporting for Construction Zone Crashes[1]
## Illinois State Police
### Instructions

The Supplemental Crash Reporting form is designed to provide some important information about automobile crashes occurring in construction work zones which is not available normally from the State of Illinois Traffic Crash Report (ITCR). In order to keep this supplemental form as short as possible, it needs to be associated with the actual crash report. The ITCR will provide data about when, where, and how the crash occurred, how many vehicles and people were involved, and the severity of the crash.

The supplemental report will be completed every time that an officer completes the ITCR on-scene of a crash. It will be stapled to the ITCR for subsequent copying and distribution of a copy to the Northwestern University Traffic Institute. Mr. Richard Raub, Research Scientist with the Institute and Principal Investigator will make arrangements with district management for handling the copies. After all relevant data are extracted, the ITCR and reference number from the supplemental report can be destroyed to prevent the possibility of the research data being subpoenaed.

**Completing the Report**

Date: Date of collision

Crash Report Number: Crash report number used on the ITCR.

1. Did the construction zone, (as pictured) contribute to the crash?

   Two examples:
   a) two vehicles involved in a sideswipe crash at the taper (merge). The crash probably would not have occurred had the merge not been required. The construction zone contributed.
   b) vehicle runs off the roadway and collides with a parked vehicle on the shoulder in the approach zone. This collision probably would have occurred even without the construction. The construction zone did not contribute; do not complete the form, *but return it regardless*.

2. Based on the construction zone diagram, check in which section the crash occurred.

The "approach" generally consists of that area prior to the transition and work area. This area starts at the first sign marking construction ahead, but for this study will be limited to the 0.5 miles prior.

The "taper" or transition is an area where one or more lanes are dropped, forcing merger. There may be two transitions if three lanes are merged to one; however, the entire area is considered the taper. There is no taper zone where lanes are shifted but not merged.

The "work area" is that section in which construction can be or is taking place. It

[1] Project sponsored by the State of Illinois, Illinois Transportation Research Council and Illinois Department of Transportation.

normally is marked by cones, barricades, and barrier walls. Within the work area may be an activity area where work actually is occurring.

The "exit" is that area after the work area ends. The first 500 feet beyond the work area should be considered the exit zone.

- Measure or estimate the number of feet *before* or *after* the point at which the work area begins (either the end of the taper and the beginning of the work area, or the point at which the lane shift starts) to where the crash occurred.

3. Any of a number of external elements could contribute to the crash. All that are believed to have contributed need to be checked. Not all contributing circumstances have been listed. Others should be added as appropriate. Use the reverse of the form if needed for continuing the description.

   For example: narrow lanes may have created a sideswipe, and a following vehicle was involved because it had no room to escape.

4. Drivers also may have contributed. In many crashes, multiple operators share the responsibility. Not all contributing circumstances have been listed. Others should be added as appropriate. Use the reverse of the form. Use the reverse of the form if needed for continuing the description. Notice that the contributing factor "speed too fast to avoid a crash" is not included. On wet roadways or under conditions of limited visibility, the driver may have been traveling too fast to control the vehicle. On dry roadways, the driver may have ben going to fast for the curve transition. If in the investigating officer's opinion, the driver was proceeding too fast to control the vehicle *and* the presence of the construction zone contributed to the crash, then the contribution "other" can be checked and noted as "too fast for conditions or the pavement, or too fast for the curve/transition."

   For example: vehicle 1 may have suddenly slowed, and the driver of vehicle 2 was distracted either from within or been watching the construction. Both drivers contributed, one by sudden slowing (possibly unexpected interference from construction equipment), and the other by being distracted.

5. Although the construction zone may have played a role, construction may not been underway. Indicate by *yes* or *no* if construction was taking place *when the crash occurred.*

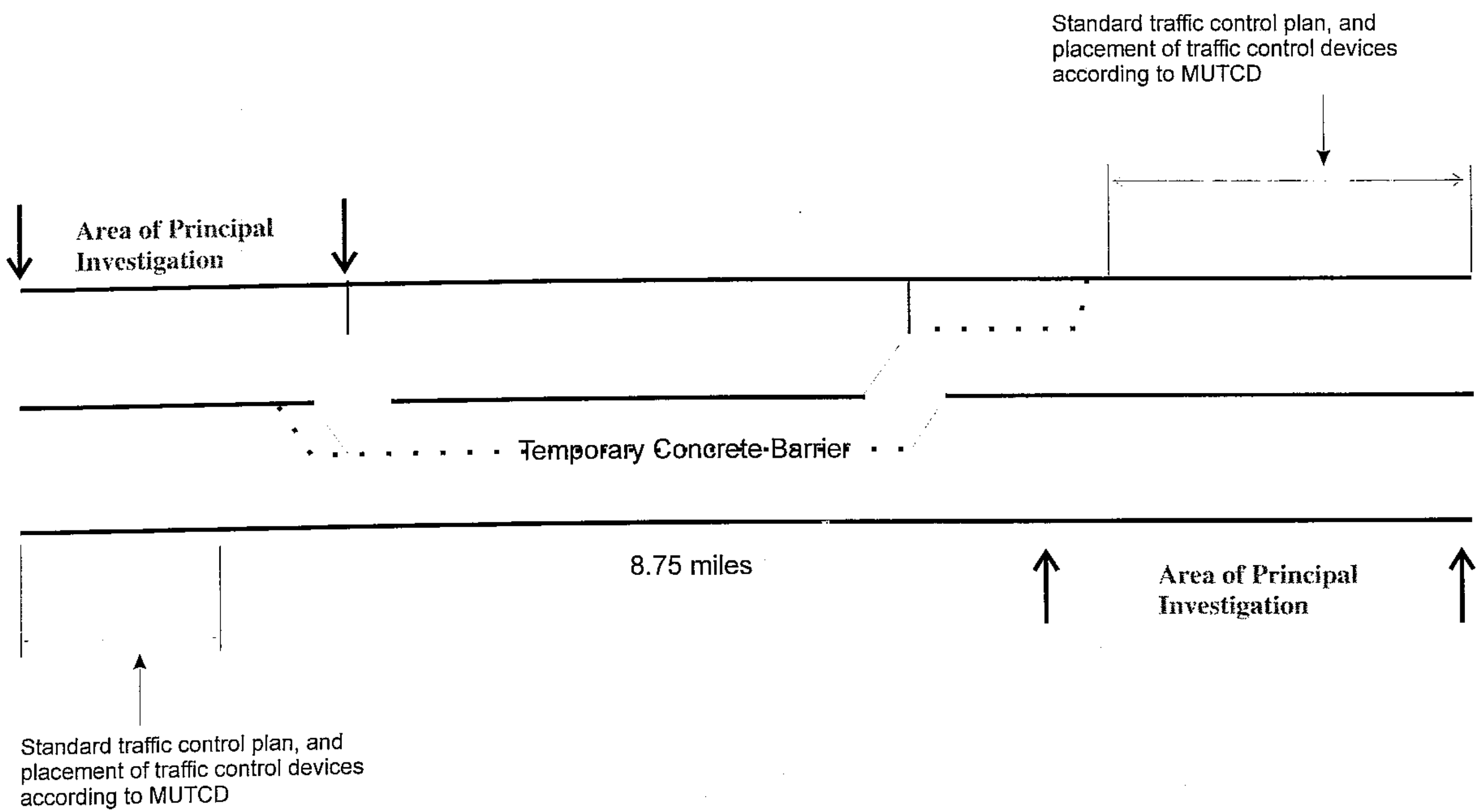
6. Could the crash have been prevented had better means of communicating with drivers through design, markings, or other aspects. Indicate *yes* or *no*. You can add comments on the reverse, or we may contact you to learn more.

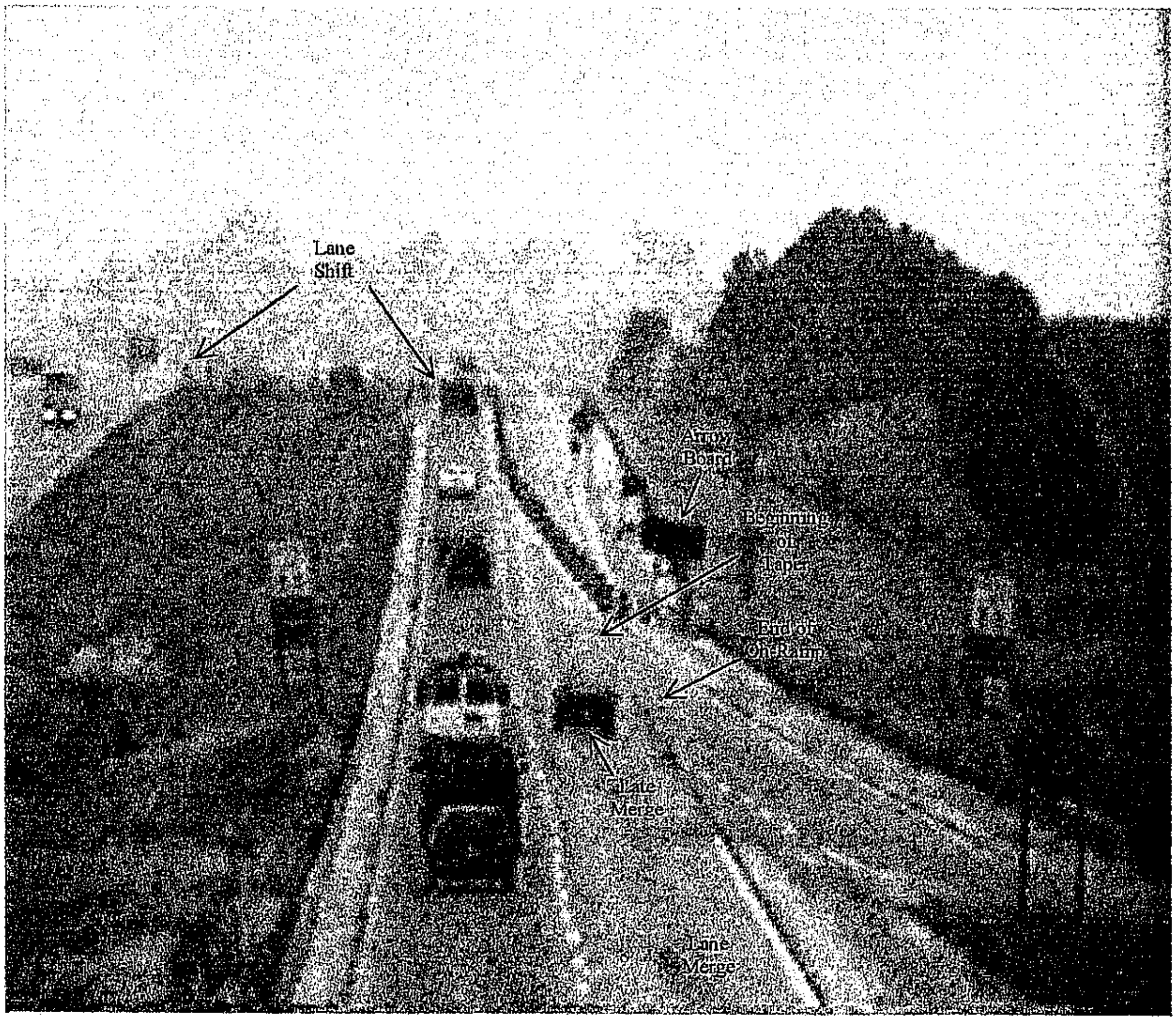
Thank you for taking time to assist the Northwestern University Traffic Institute and State of Illinois, DOT with this important project.

# Appendix D

## Photographs of Five Sites Selected for Onsite Observations

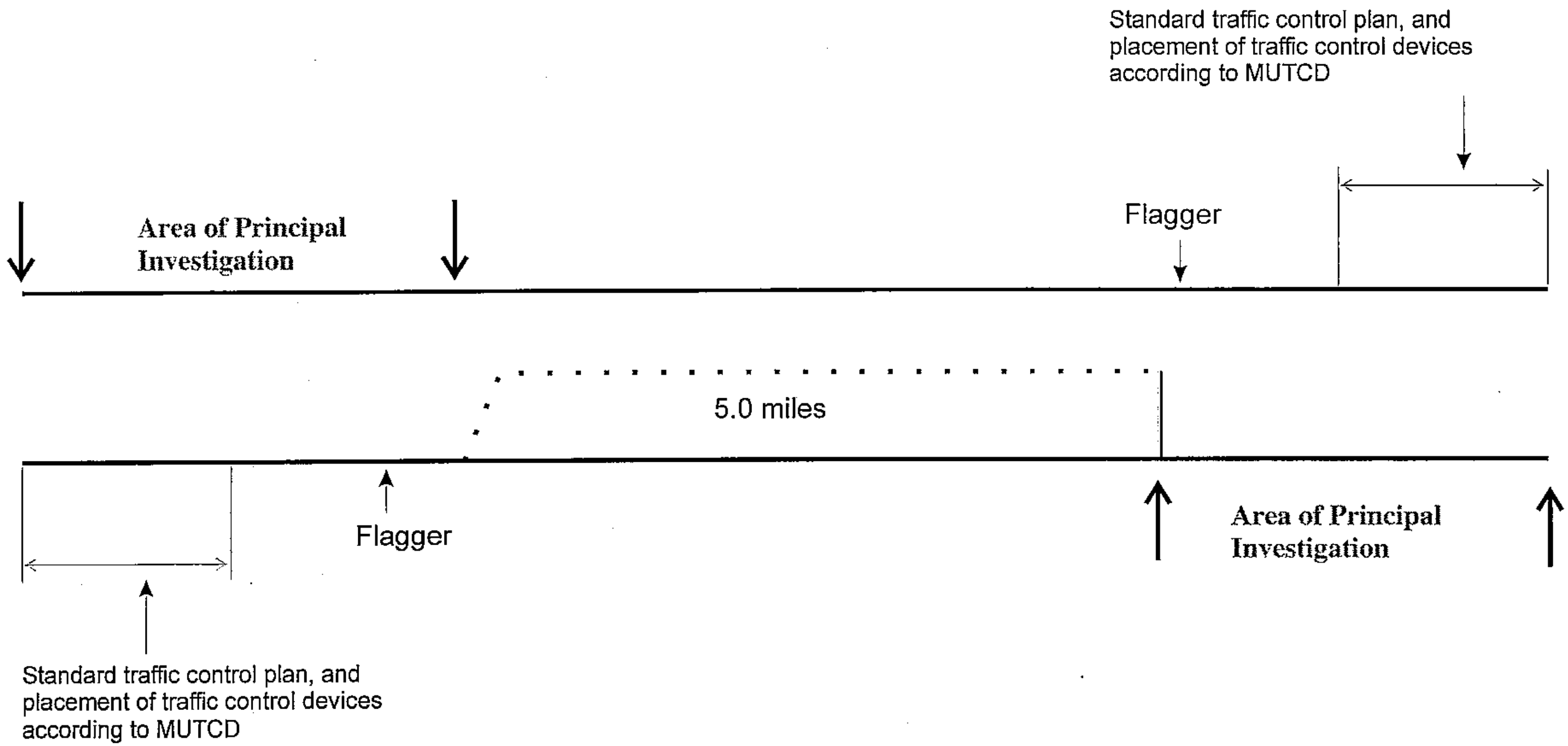
## I-74 North of Woodhull

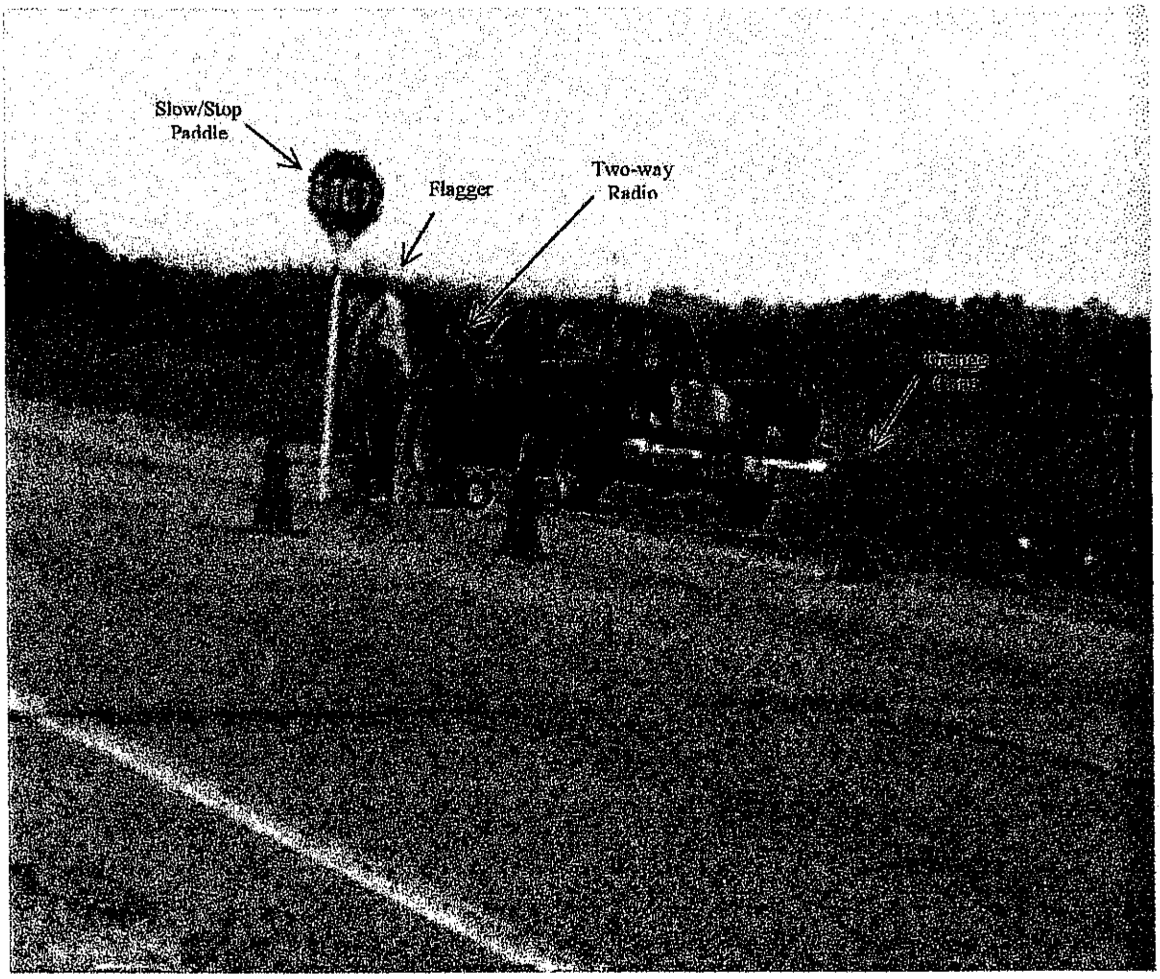




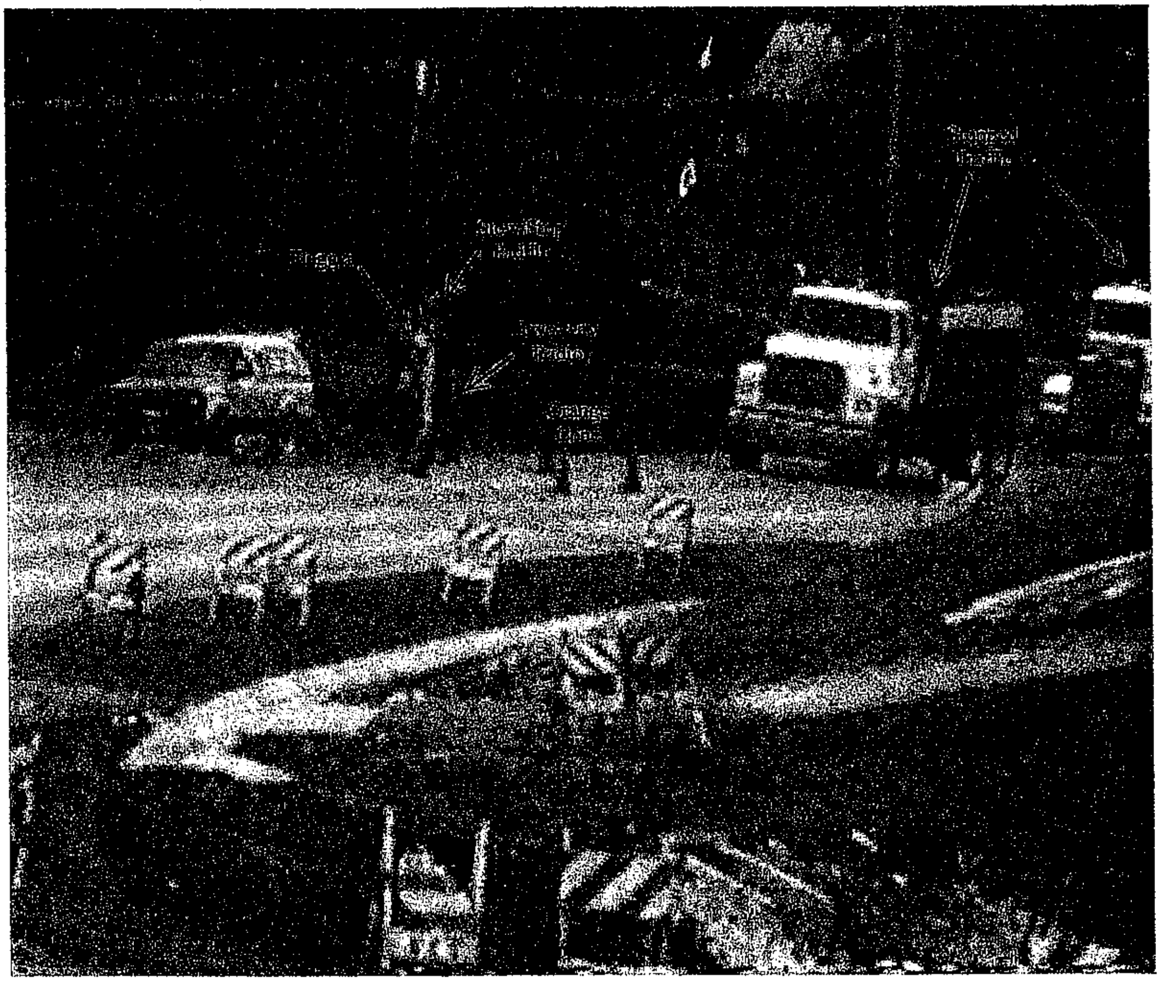

**1.** I 74 North of Woodhull and South of Route 81

## US 67 South of Rock Island

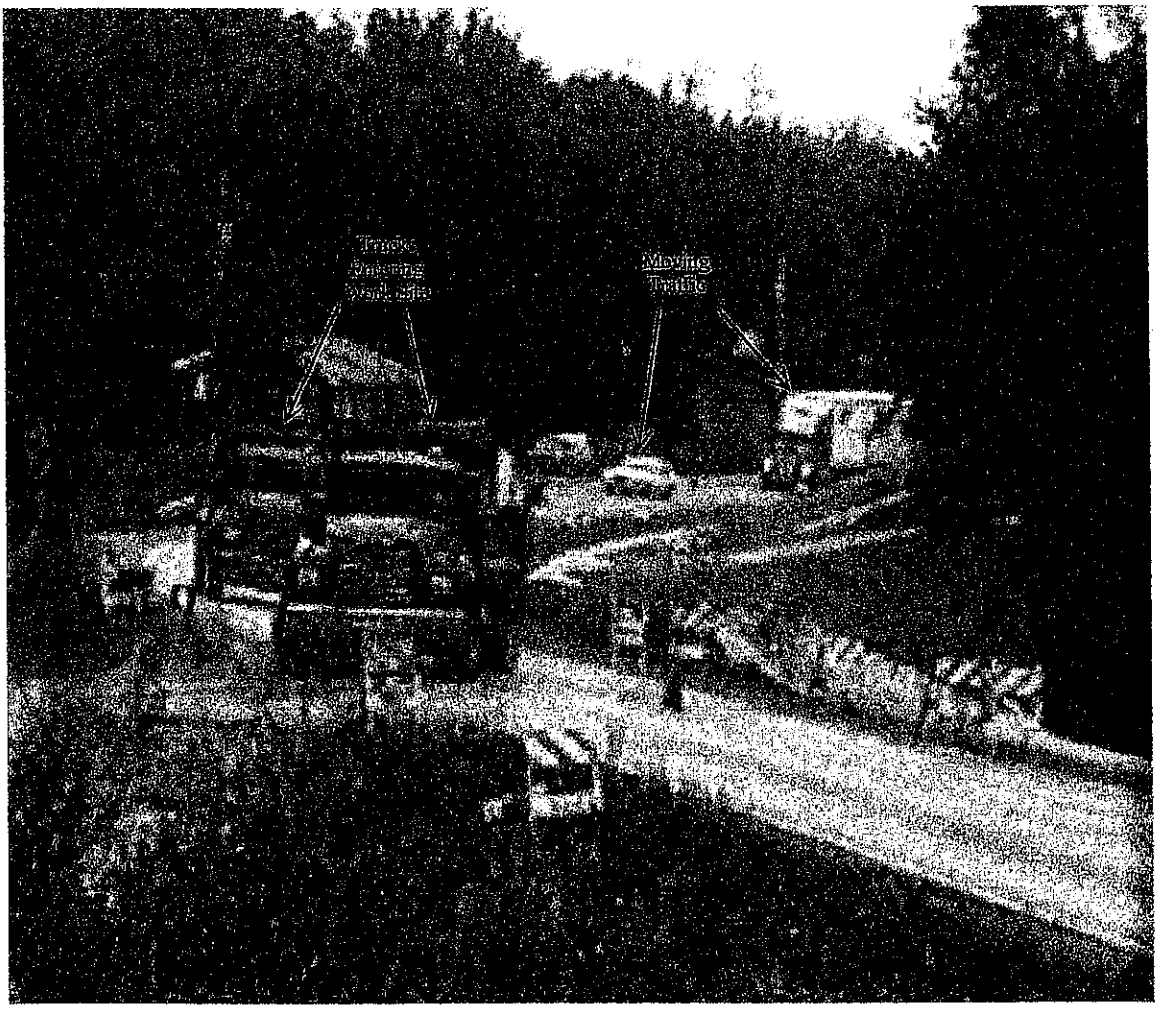




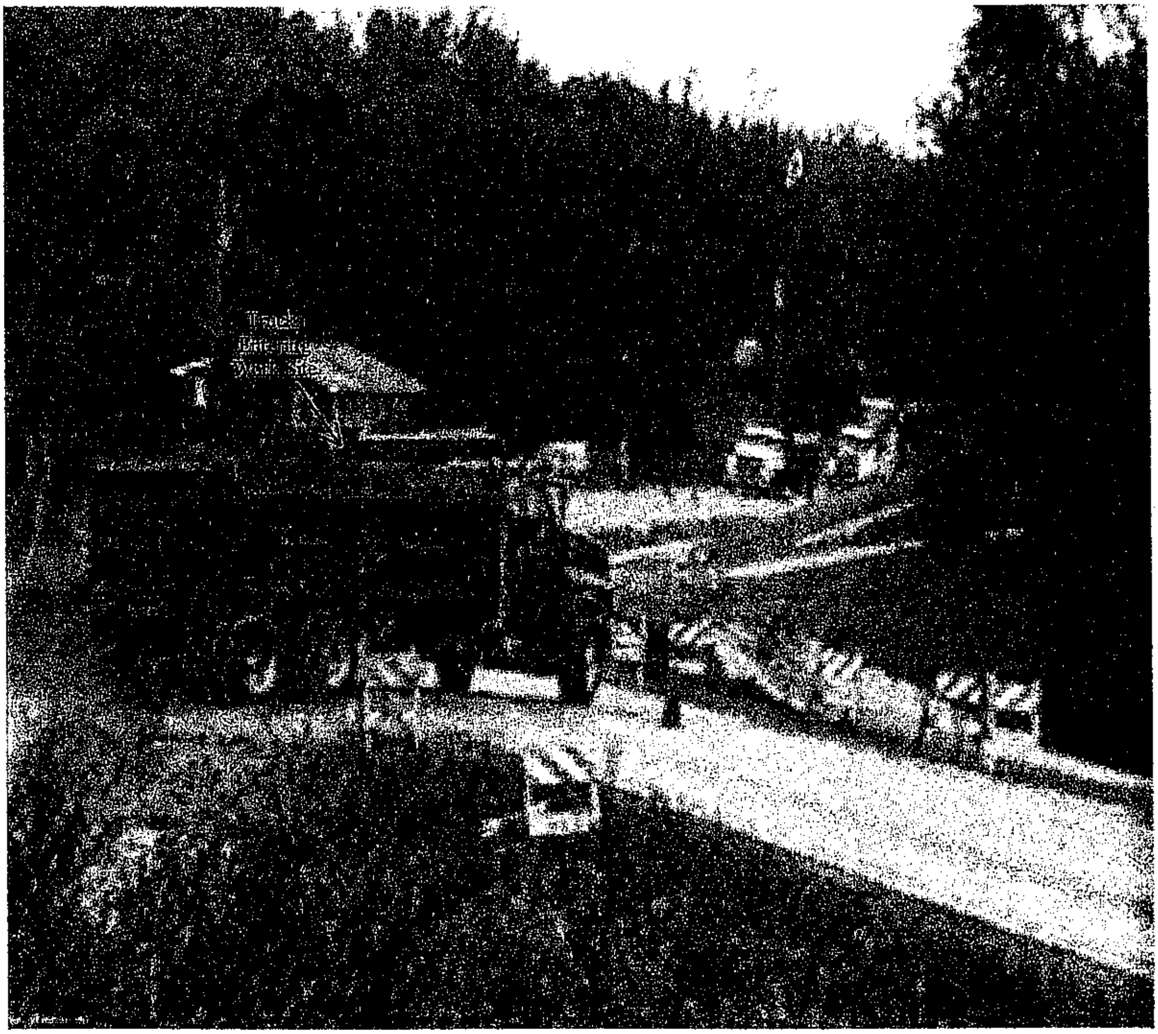

**2. First Flagger on US 67 South of Rock Island and North of Viola**



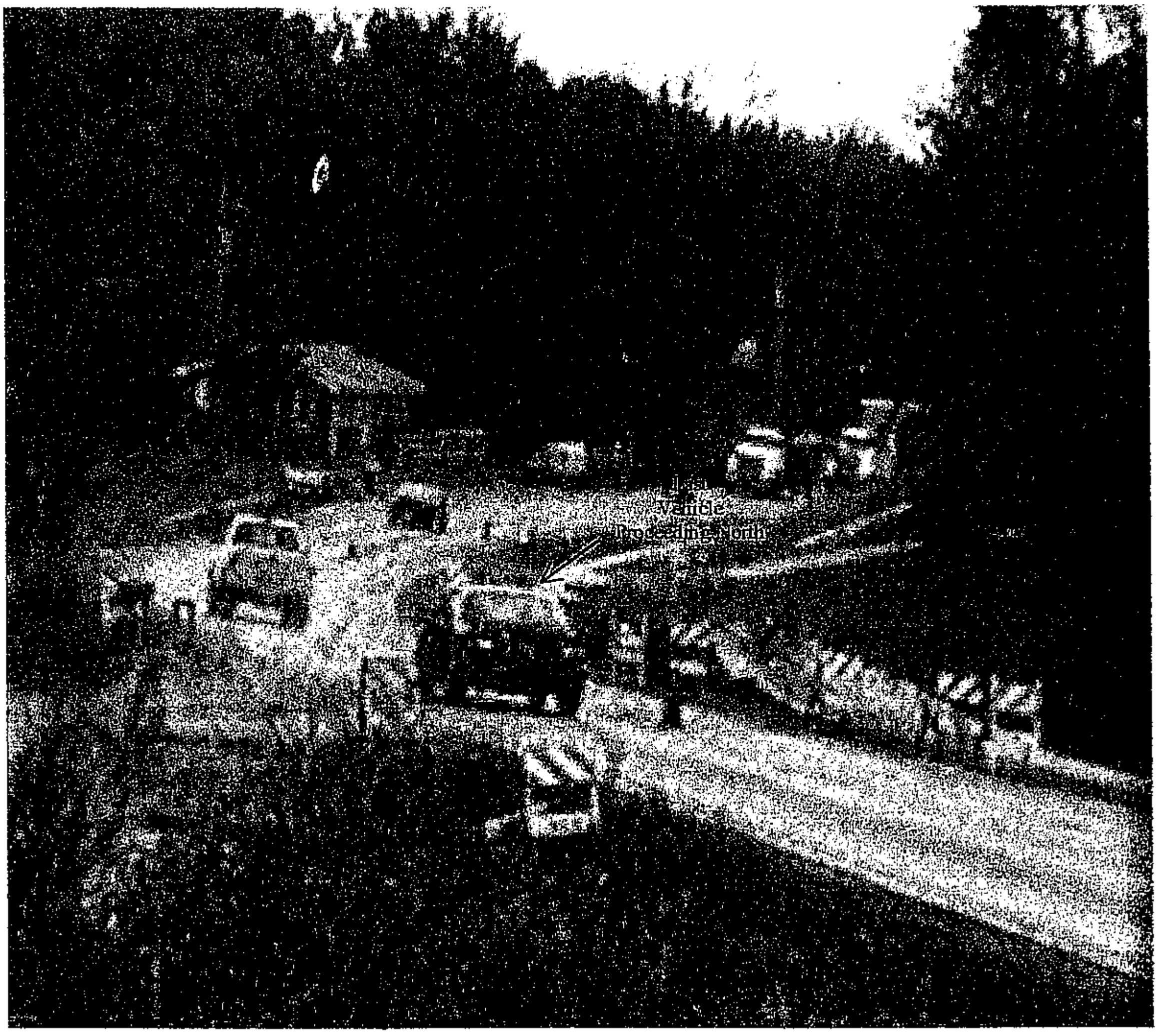

**3. Second Flagger on US 67 South of Rock Island and North of Viola**




**4.** Truck Entering Work Site on US 67 South of Rock Island and North of Viola

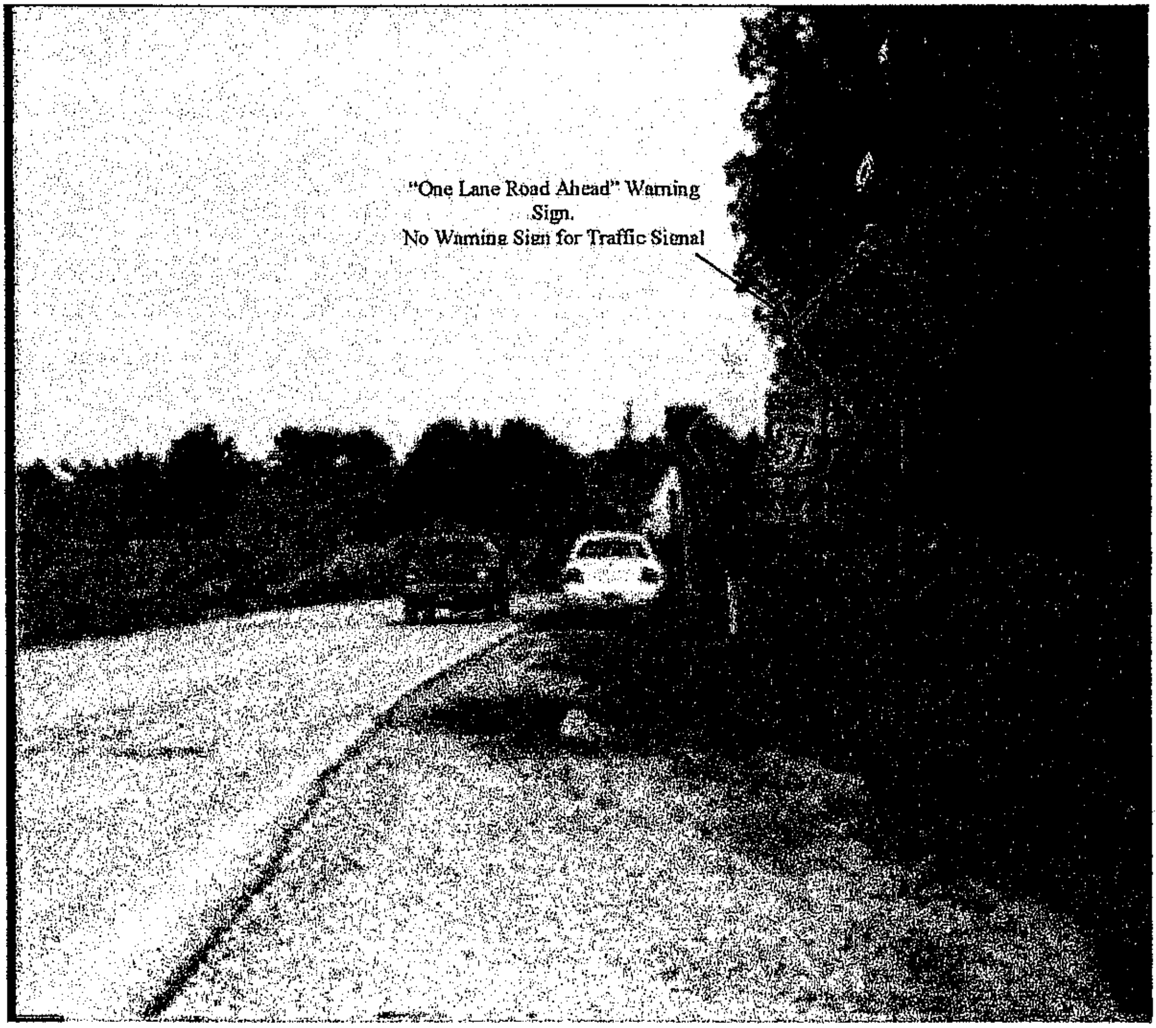


**5. Truck Leaving Work Site on US 67 South of Rock Island and North of Viola**

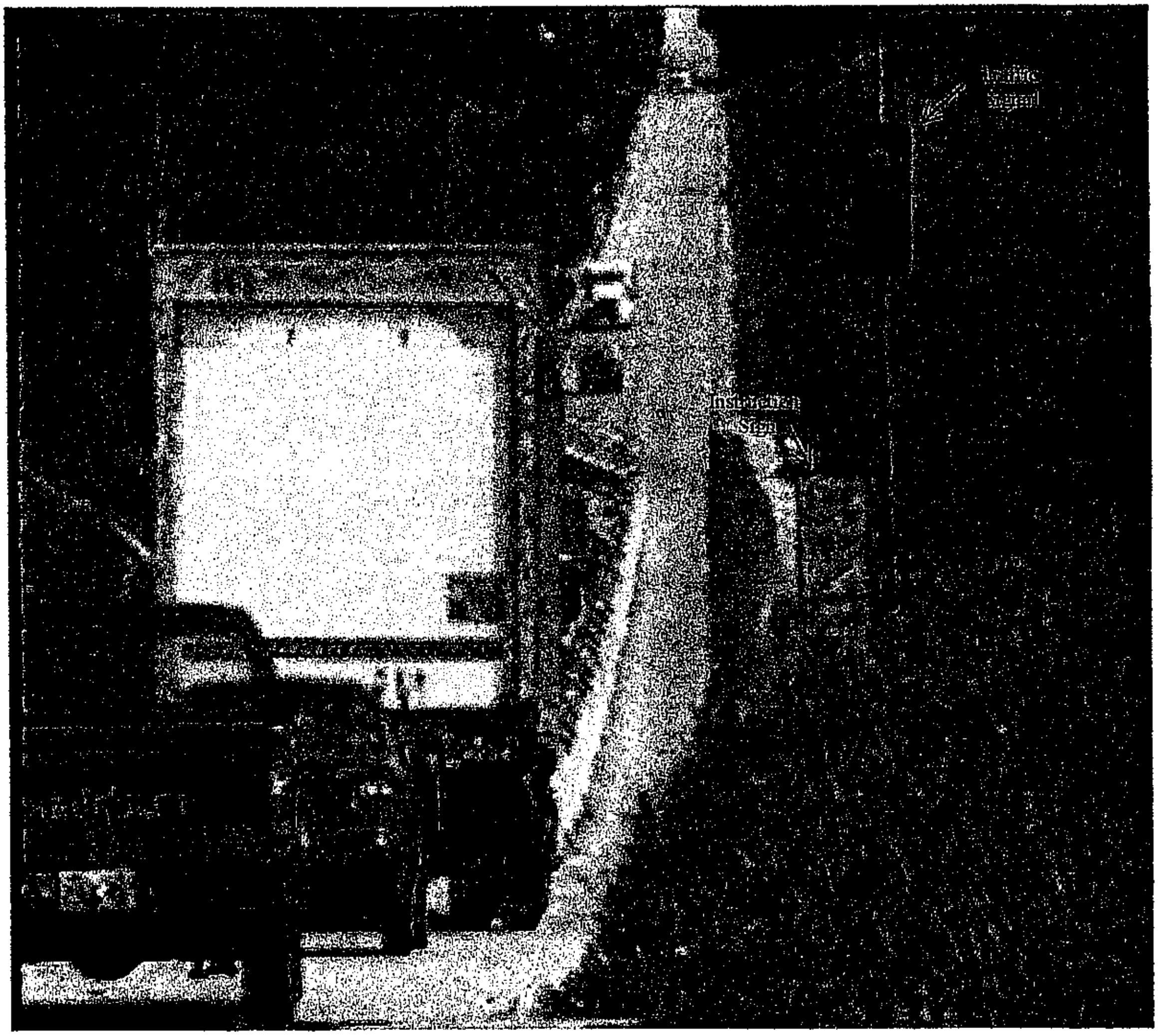



**6. US 67 South of Rock Island and North of Viola**

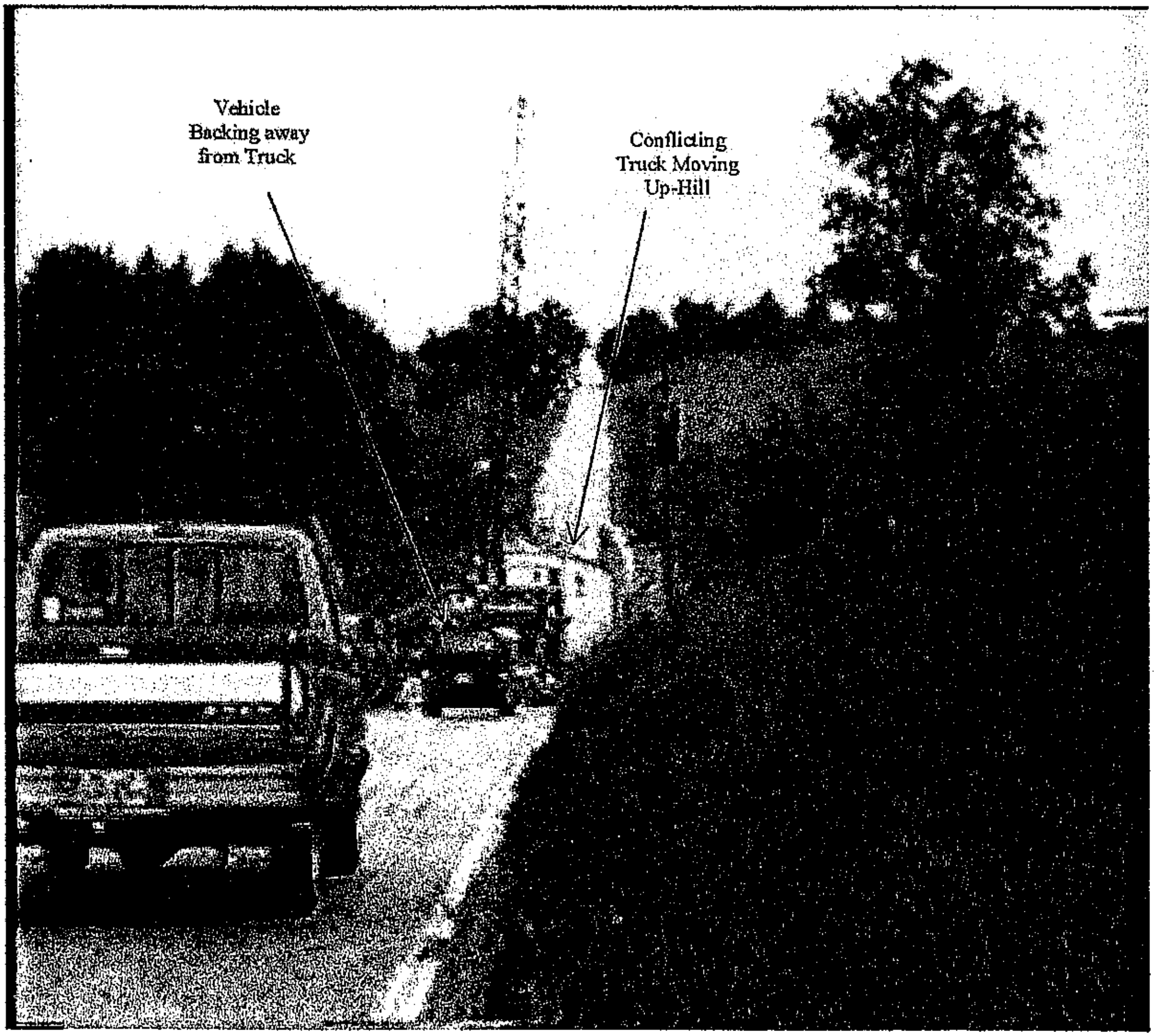

**7. Worker Crossing Road on US 67 South of Rock Island and North of Viola**




8. Warning Signs on US 67 South of Viola and North of Alexis



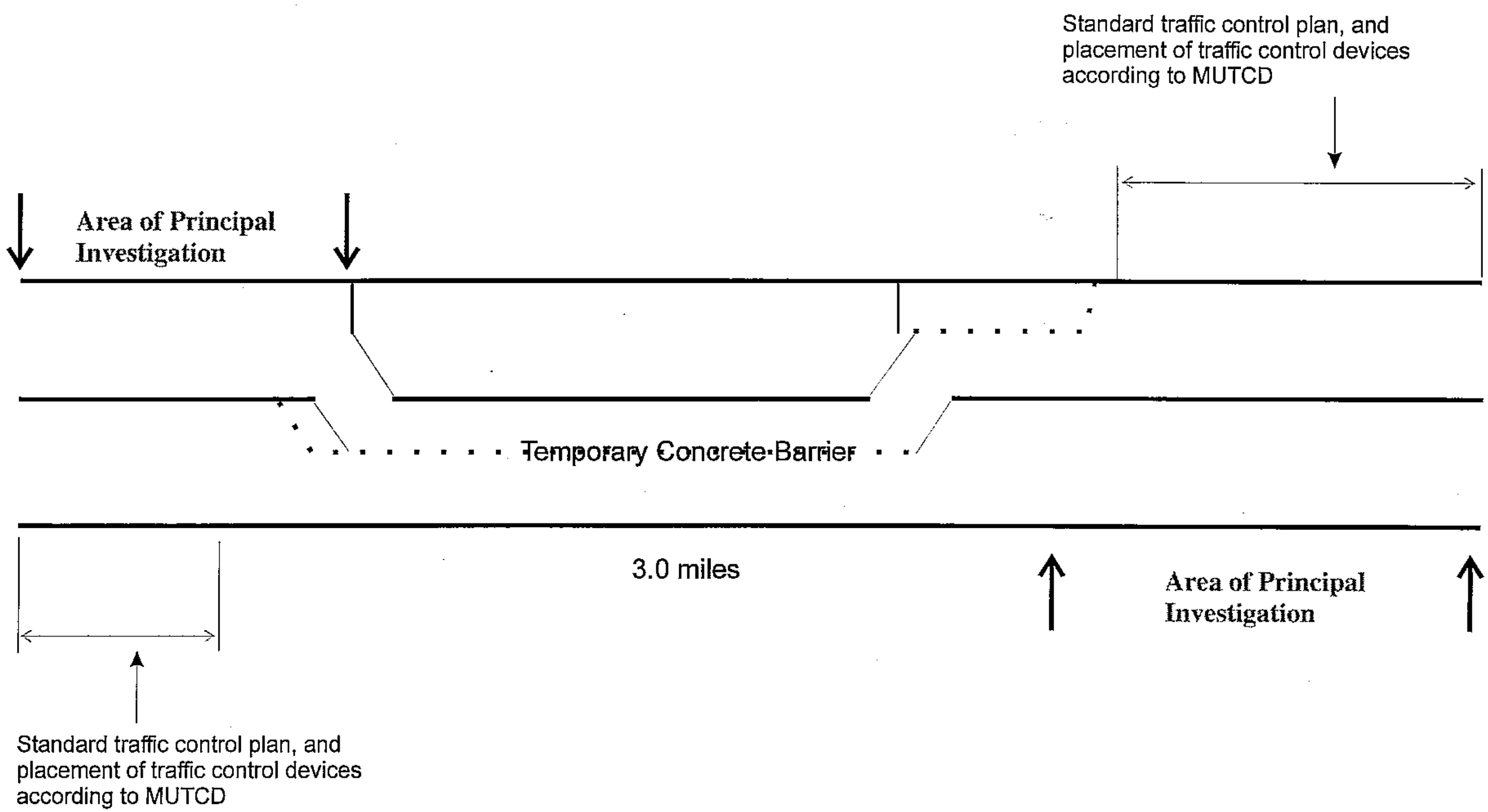
9. Traffic Signal Control on US 67 South of Viola and North of Alexis

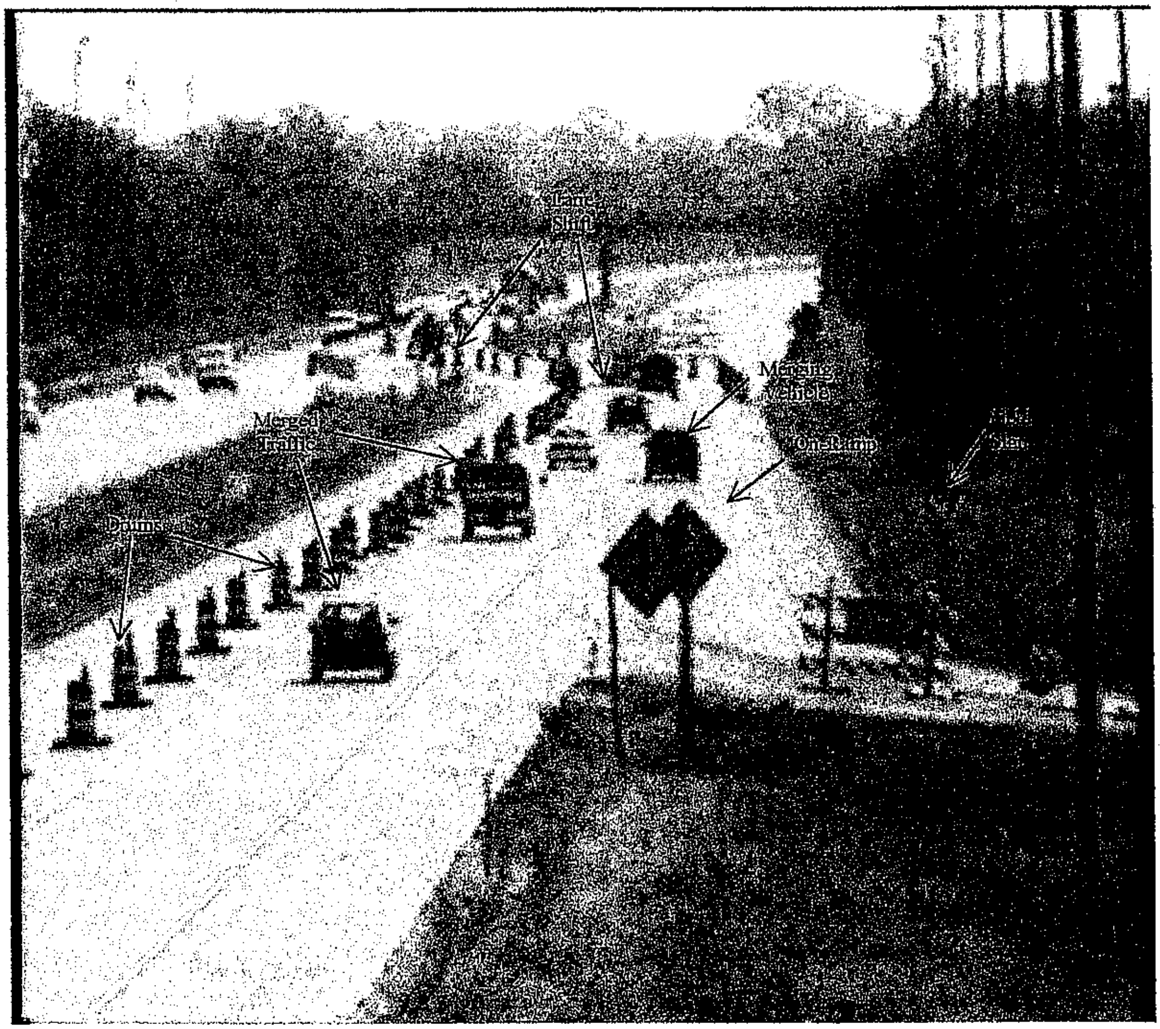



**10. Conflicting Traffic on US 67 South of Viola and North of Alexis**

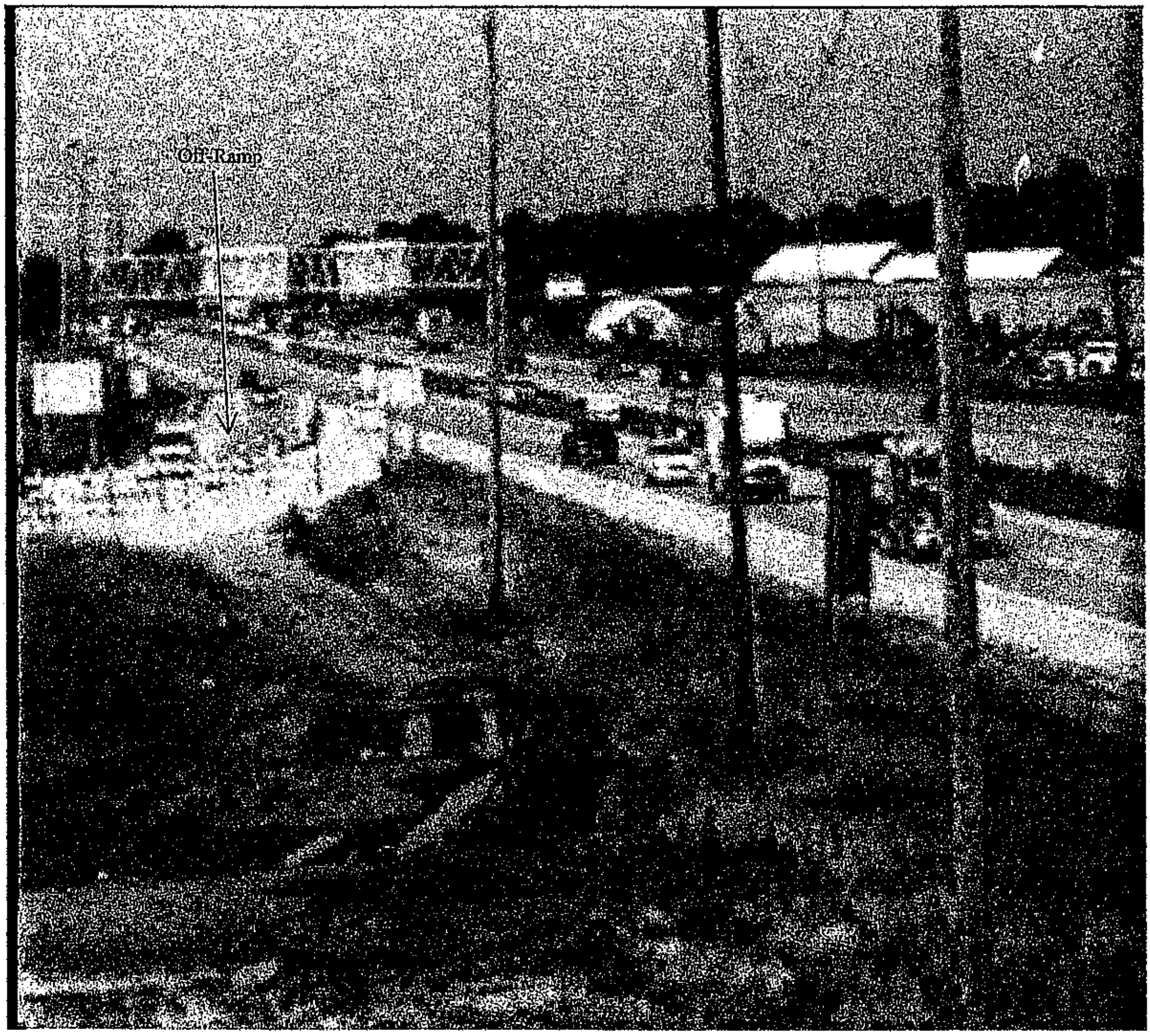

.11. IL 47 Interchange

# I-80 Morris

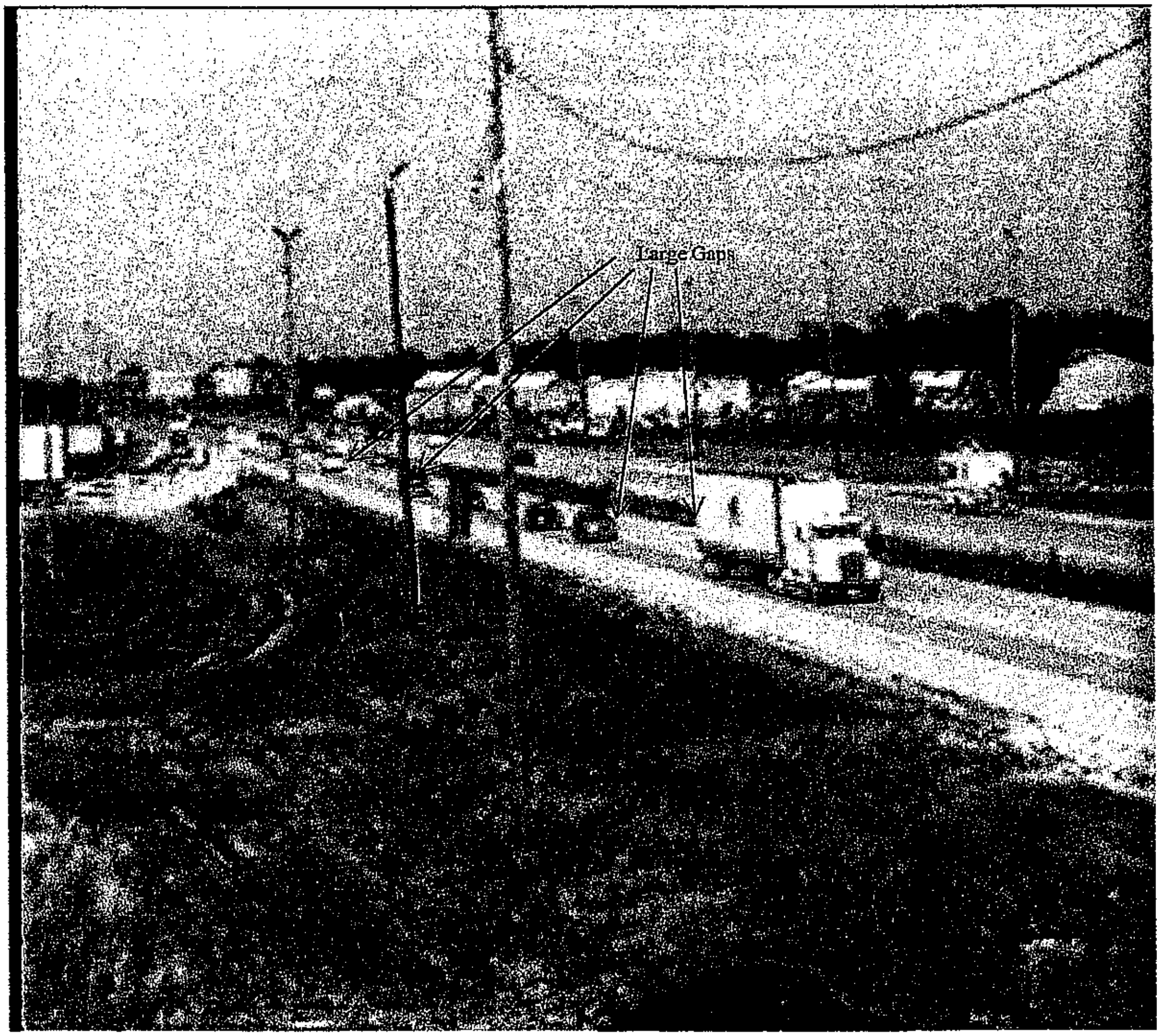

Standard traffic control plan, and
placement of traffic control devices
according to MUTCD
Area of Principal
Investigation
Temporary Concrete Barrier
3.0 miles
Area of Principal
Investigation
Standard traffic control plan, and
placement of traffic control devices
according to MUTCD



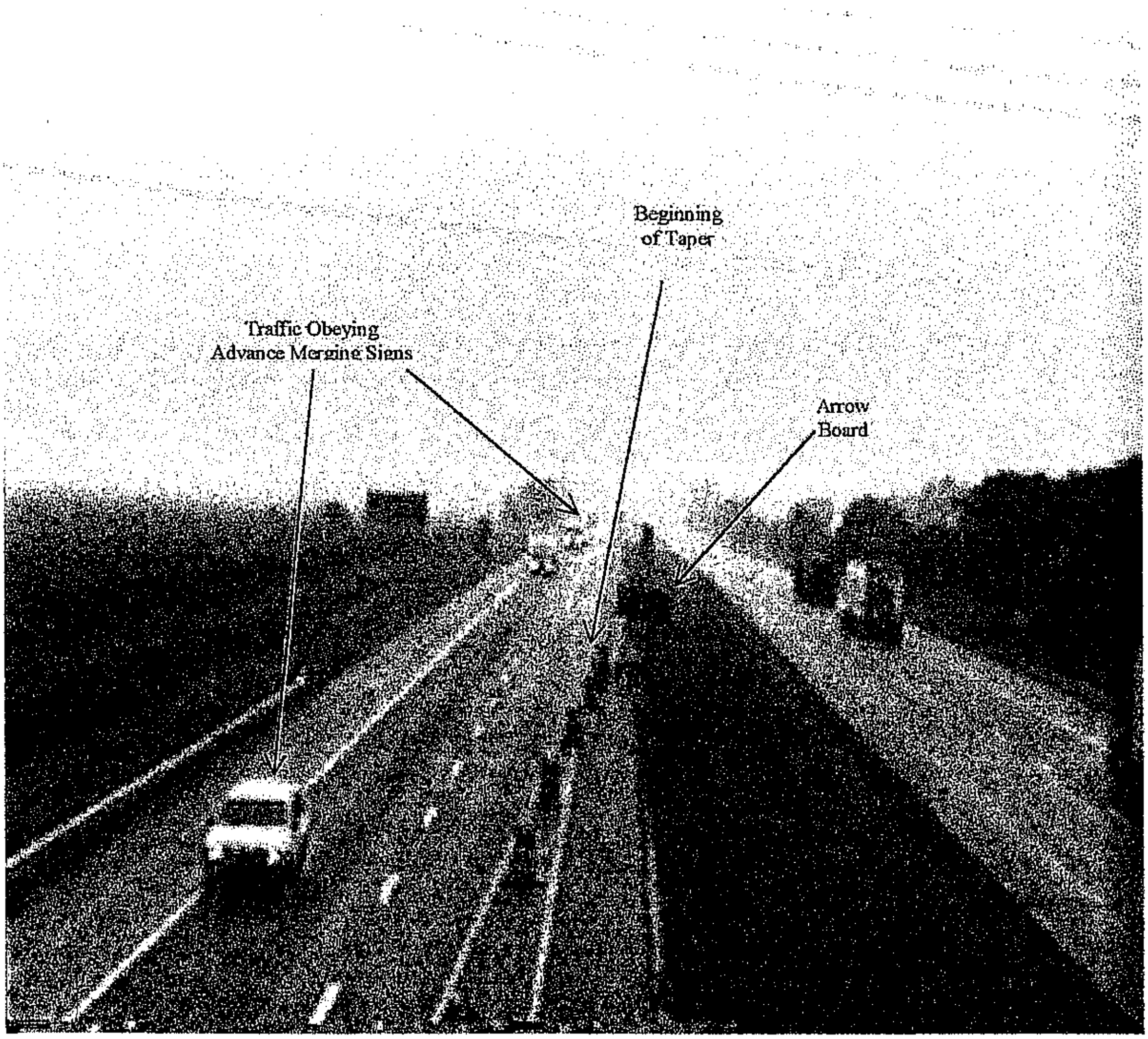

.12. Merge and Lane Shift Westbound on I 80 East of Morris




**13. Off-Ramp Westbound on I 80 East of Morris**

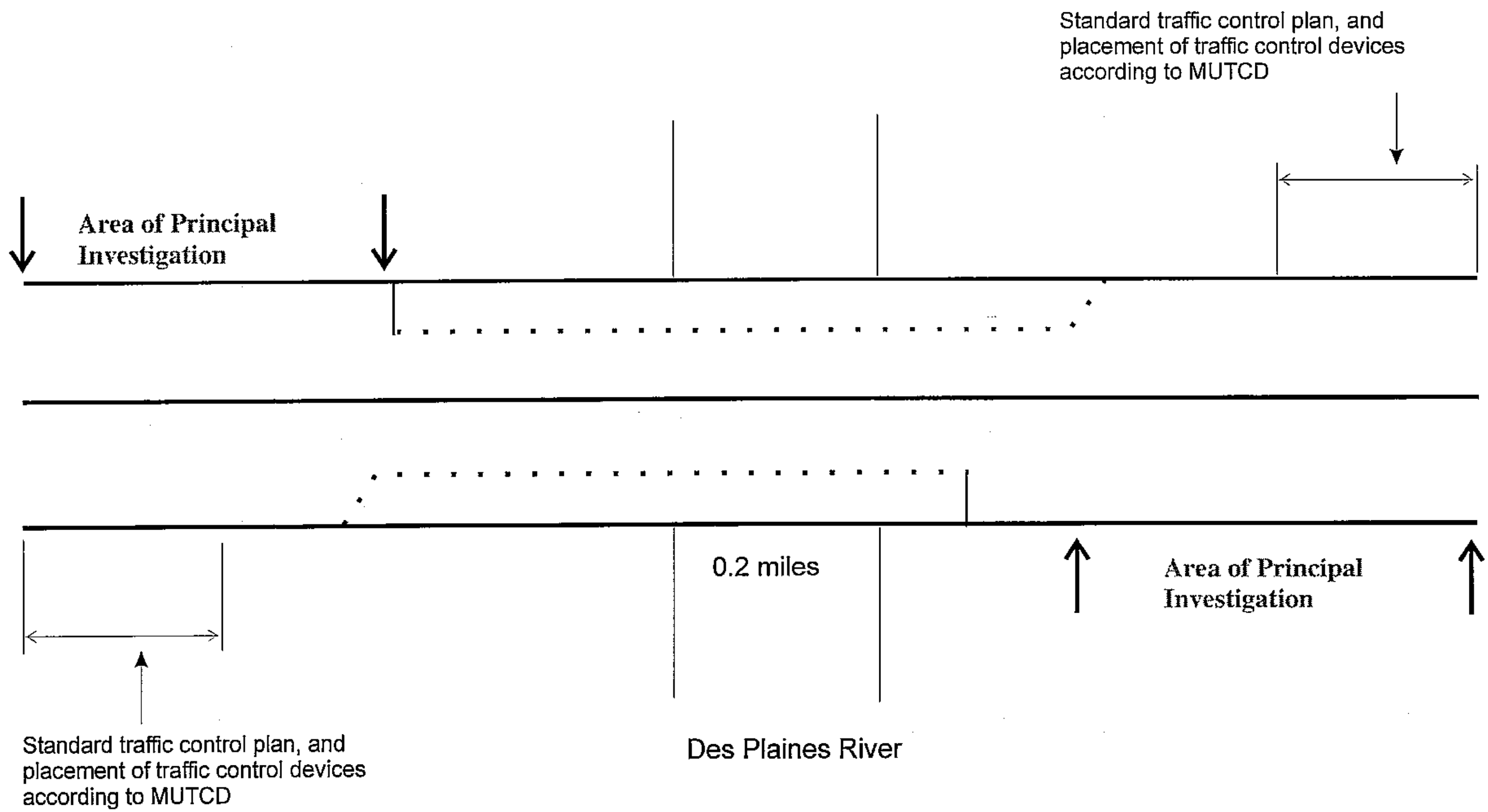


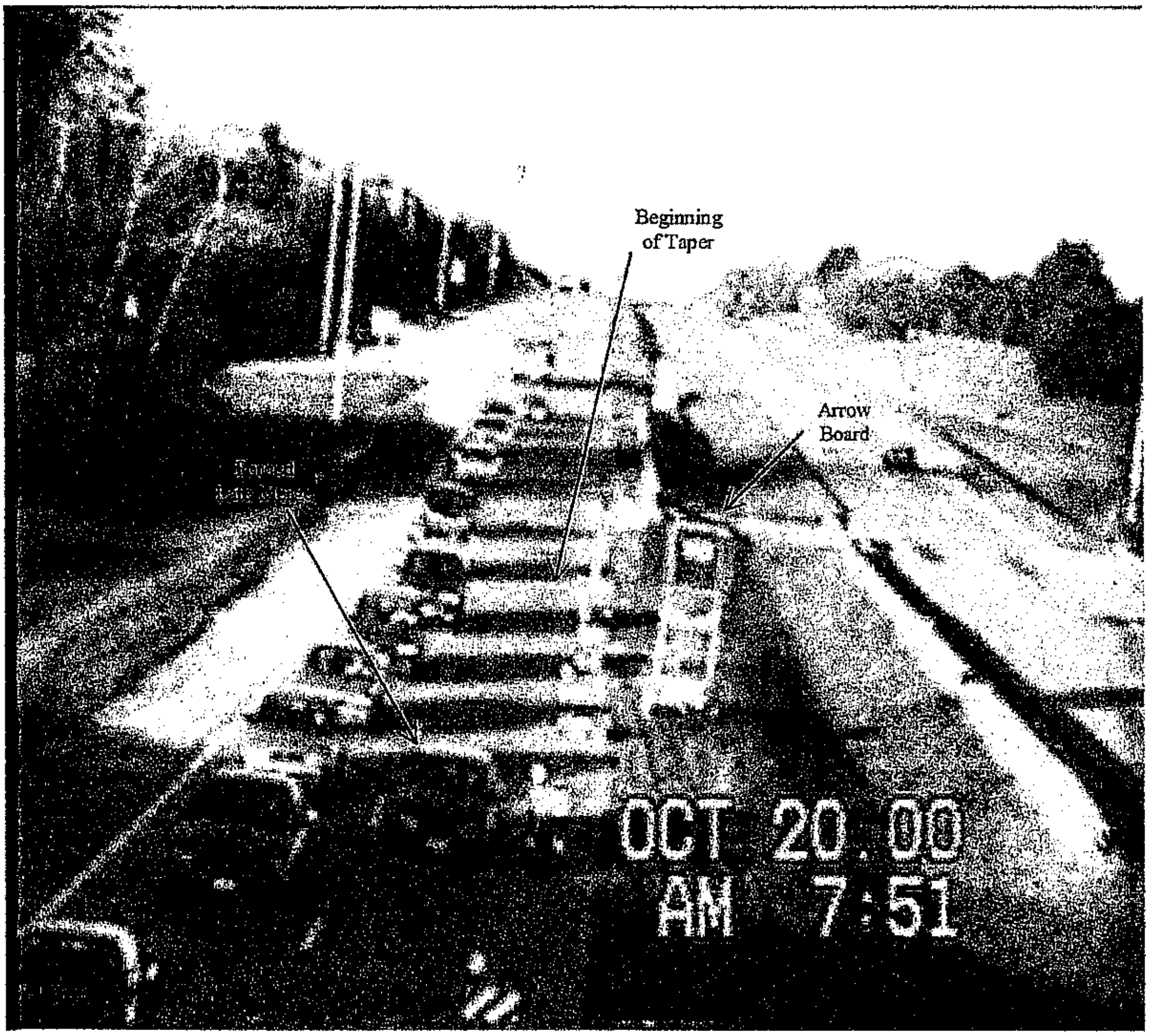

.14. Large Gaps Westbound on I 80 East of Morris



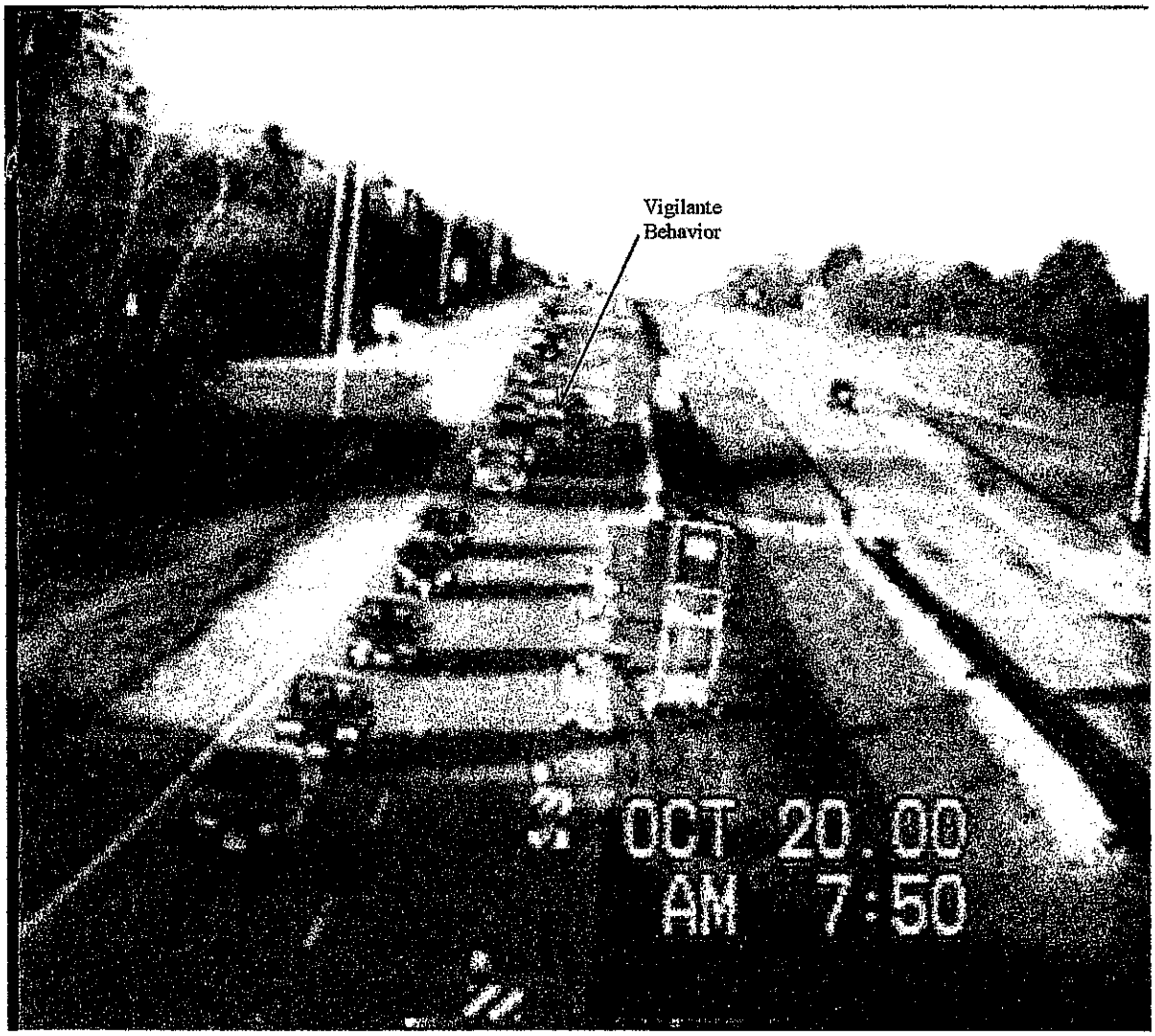

.15. Eastbound Traffic on I 80 East of Morris

# IL 120 - Gurnee

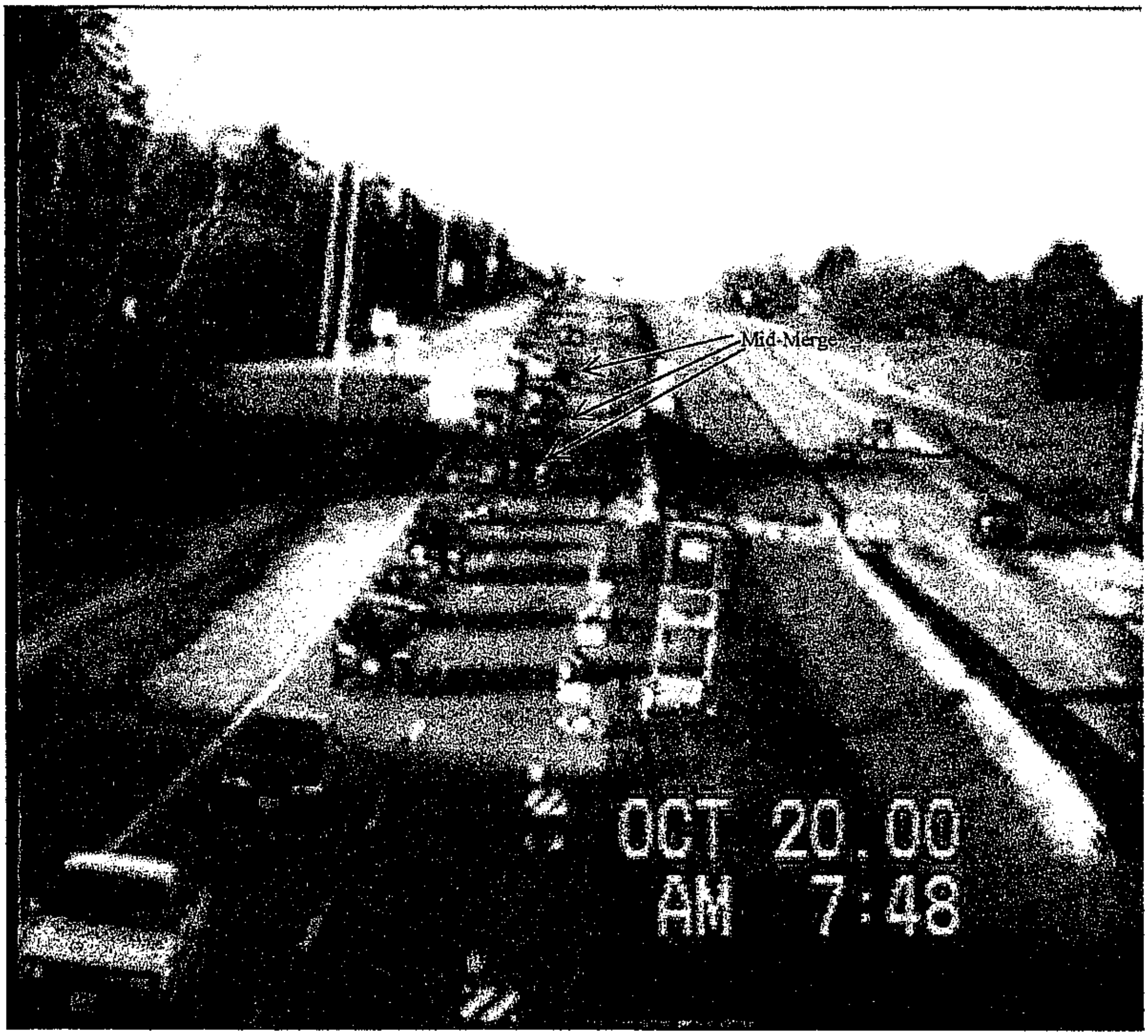




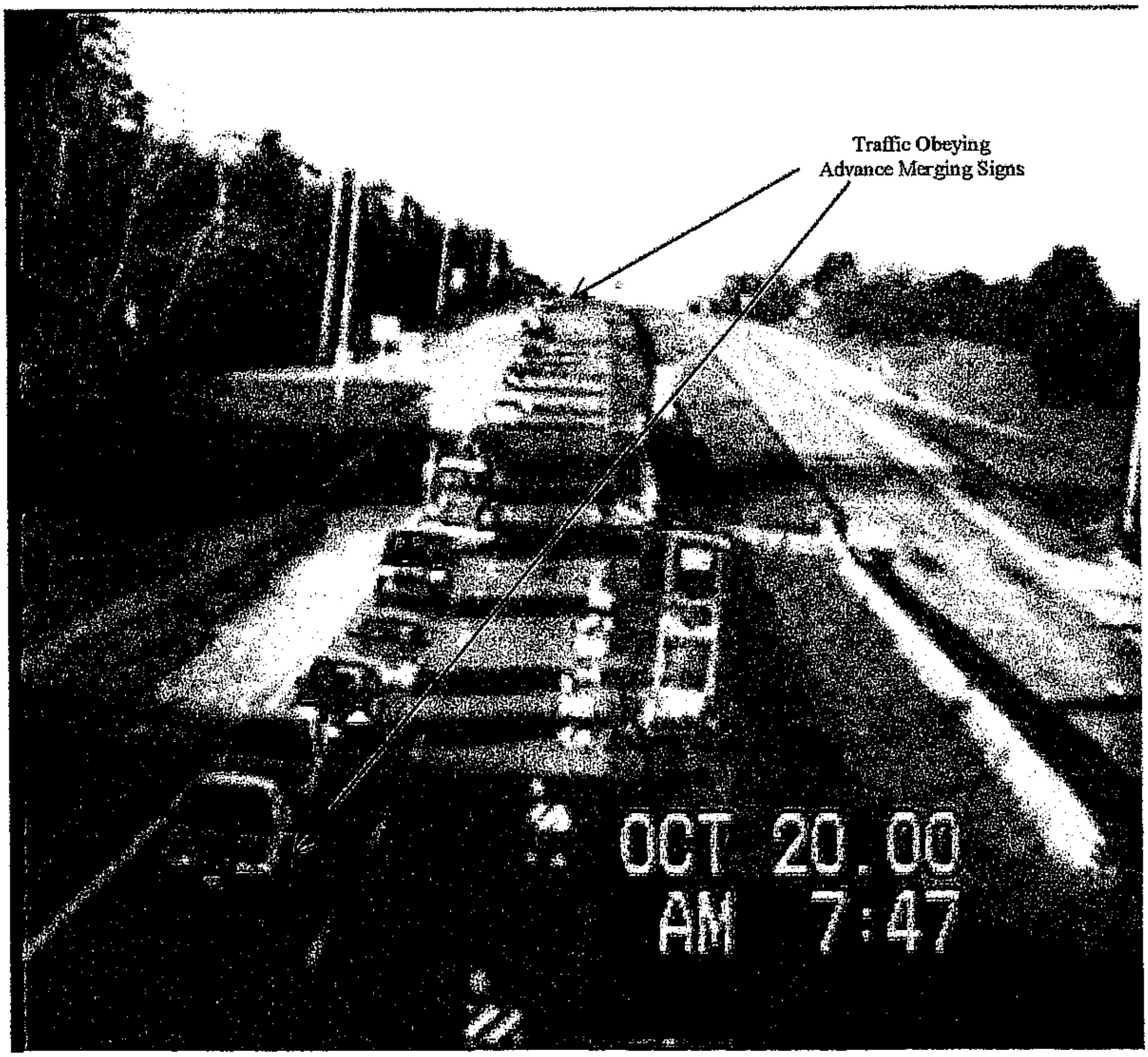

. 16. Late Merge on IL 120 in Gurnee




**17. Vigilante behavior on IL 120 in Gurnee**

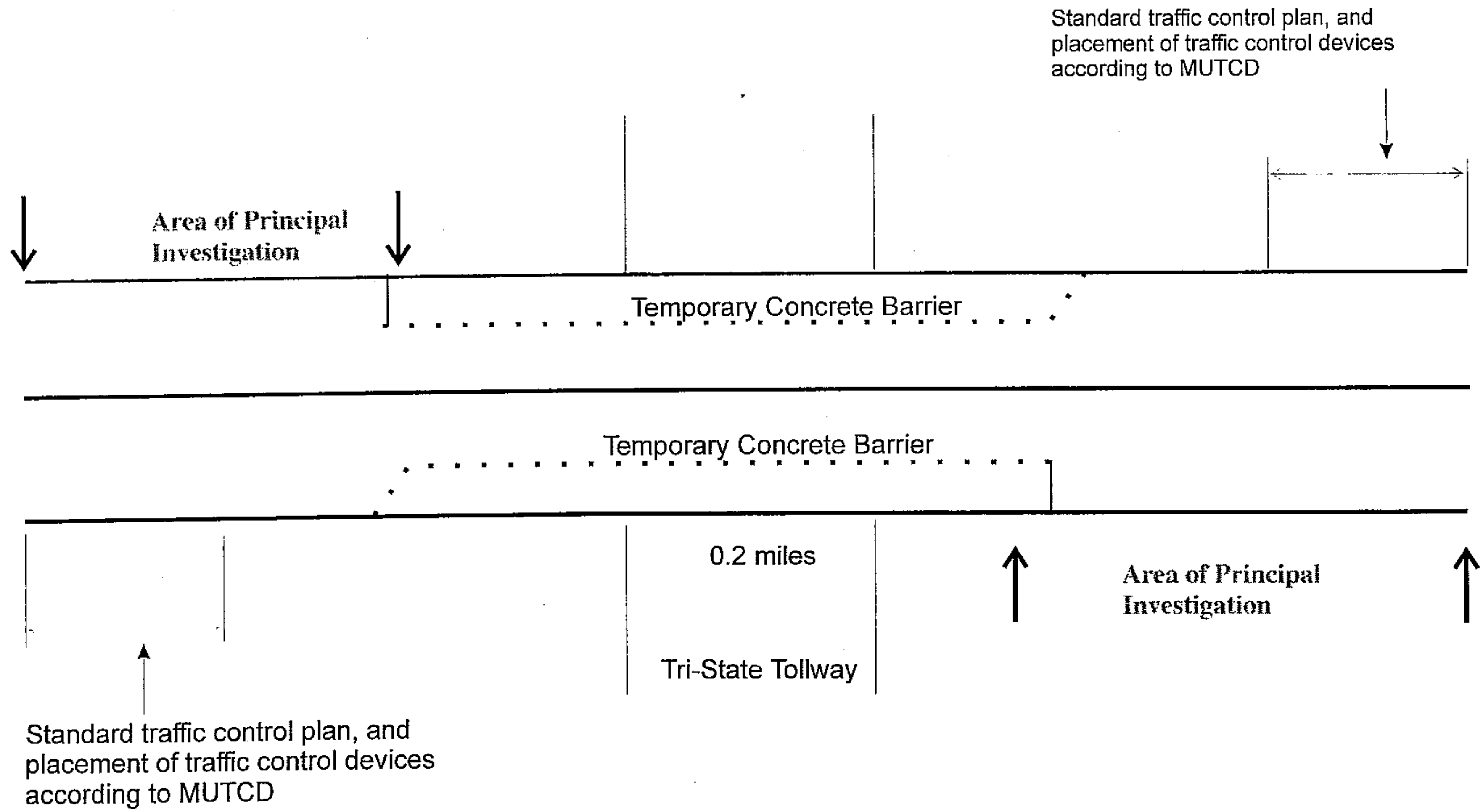



.18. Mid-Merge on IL 120 in Gurnee




19. Normal Behavior on IL 120 in Gurnee

# IL 68 - Northbrook



## Appendix E
## List of Codes for Workzone Traffic Control Devices

0 Miscellaneous
- 0 none

1 Mainline, in Place
- 100 drums
- 101 left vertical panels
- 102 right vertical panels
- 103 temporary concrete barriers
- 104 temporary concrete barriers with reflectors
- 105 barricades (type III)
- 106 barricades (type III) with burning lights
- 107 cones
- 108 temporary pavement markings (type III)
- 109 none

2 Mainline, Signage, Before Zone
- 200 Road Construction 5 Miles
- 201 Road Construction 4 Miles
- 202 Road Construction 3 Miles
- 203 Road Construction 2 Miles
- 204 Road Construction 1 Mile
- 205 Road Construction ½ Mile
- 206 Road Construction 1500 feet
- 207 Road Construction 1000 feet
- 208 Road Construction 500 feet
- 209 Workzone Speed Limit
- 210 Diamond Lane Shift
- 211 All Traffic Lane Shift
- 212 Advance Information Sign
- 213 Detour Recommended
- 214 Lane Drop Left
- 215 Lane Drop Right
- 216 Lane Narrows Ahead
- 217 Do Not Pass
- 218 None

3 Mainline Signage, in Zone
- 300 Speed Limit
- 301 Trucks Use Left Lane
- 302 Trucks Use Right Lane
- 303 Do Not Pass
- 304 Lane Shift
- 305 Lane Narrow Ahead
- 306 Be Prepared to Stop
- 307 Keep Right
- 308 Keep Left
- 309 Under Construction
- 310 Ramp Closed Ahead
- 311 None

4 Mainline, Traffic Control, Before Zone
- 400 Variable Message Signs
- 401 None

5 Mainline, Traffic Control, in Zone
- 500 Variable Message Signs
- 501 Arrow Signs
- 502 Temporary Entrance to Driveways
- 503 Flaggers
- 504 None

6 Pavement Traffic Control Devices
- 600 Rumble Strips
- 601 Arrows
- 602 None

7 Ramp Traffic Control
- 700 Drums
- 701 Cones
- 702 Barricades with Flashing Lights
- 703 Ramp Closed
- 704 Flagger
- 705 None

8 Temporary Signals
- 800 Temporary Signals
- 801 None

9 Lighting
- 900 Temporary Lighting
- 901 None

## Appendix F

## Individual Hypothesis Testing of Interstate and Arterial Roadways

**Table F1**
**Regression Models to Predict Overall Crash Rates at Interstate Work zones**

| Independent Variables | Dependent Variable: Workzone Crash Rate for All Seven Interstate Sites | | | | |
|---|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 3** | **Model 4** | **Model 5** |
| Intercept | -1.33 (-5.34) | 0.37 (0.67) | 1.16 (1.46) | 1.39 (3.31) | 0.36 (0.67) |
| Crash rate before workzone | -0.02 (-0.51) | 1.48 (4.25) | 1.35 (3.96) | 0.06 (0.13) | 1.48 (4.25) |
| 100 = Drums | Dropped out | | | | |
| 103 = Concrete barriers | 3.64 (6.42) | | | | |
| 105 = Barricades | Dropped out | | | | |
| 209 = Workzone speed limit | 2.69 (7.63) | | | | |
| 501 = Flashing arrow sign | -0.71 (-1.66) | | | | |
| 503 = Flagger | -0.23 (-1.66) | | | | |
| 600 = Rumble strips | Dropped out | | | | |
| Drums and barricades | | Dropped out | | | |
| Drums and workzone speed limit | | | -0.86 (-1.31) | | |
| Concrete barriers and workzone speed limit | | | | 3.05 (3.54) | |
| Flashing arrow sign and flagger | | | | | Dropped out |
| $R^2$ | 0.994 | 0.740 | 0.772 | 0.921 | 0.740 |

$t_{0.05}$ with df = 6, 2.47

**Table F2**
**Regression Models to Predict Overall Crash Rates at Non-limited Access Road Workzones**

| Independent Variables | Dependent Variable: Workzone Crash Rate for All 14 Non-limited Access Sites | | | | |
|---|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 3** | **Model 4** | **Model 5** |
| Intercept | -4.10 (-0.85) | -0.42 (-0.41) | 0.80 (0.86) | 0.85 (0.94) | 1.18 (1.23) |
| Crash rate before workzone | 1.23 (9.80) | 1.13 (17.39) | 1.09 (15.78) | 1.09 (16.10) | 1.12 (16.30) |
| 100 = Drums | 4.97 (2.27) | | | | |
| 103 = Concrete barriers | 3.68 (0.13) | | | | |
| 105 = Barricades | 4.58 (1.13) | | | | |
| 209 = Workzone speed limit | -1.16 (-0.36) | | | | |
| 501 = Flashing arrow sign | -3.27 (-0.12) | | | | |
| 503 = Flagger | -0.50 (-0.02) | | | | |
| 600 = Rumble strips | 2.52 (0.78) | | | | |
| Drums and barricades | | 2.30 (1.73) | | | |
| Drums and workzone speed limit | | | -0.10 (-0.38) | | |
| Concrete barriers and workzone speed limit | | | | -0.19 (-0.74) | |
| Flashing arrow sign and flagger | | | | | -1.51 (-1.12) |
| $R^2$ | 0.969 | 0.960 | 0.950 | 0.952 | 0.955 |

$t_{0.05}$ with df = 13, 2.16

**Table F3**
**Regression Models to Predict Side-Swipe, Same-Direction Crash Rates at Non-limited Access Road Workzones**

| Independent Variables | Dependent Variable: Side-Swipe, Same-Direction Crash Rate | |
|---|---|---|
| | Model 6 | Model 7 |
| Intercept | 0.06 (0.20) | -0.004 (-0.02) |
| Crash rate before workzone | 1.30 (4.89) | 1.24 (5.07) |
| 100 = Drums | 0.49 (1.41) | 0.27 (1.03) |
| 103 = Concrete barriers | 0.32 (0.63) | |
| 209 = Workzone speed limit | -0.12 (-1.21) | |
| 501 = Flashing arrow sign | -0.15 (-0.44) | |
| $R^2$ | 0.616 | 0.662 |

$t_{0.05}$ with df = 13, 2.16

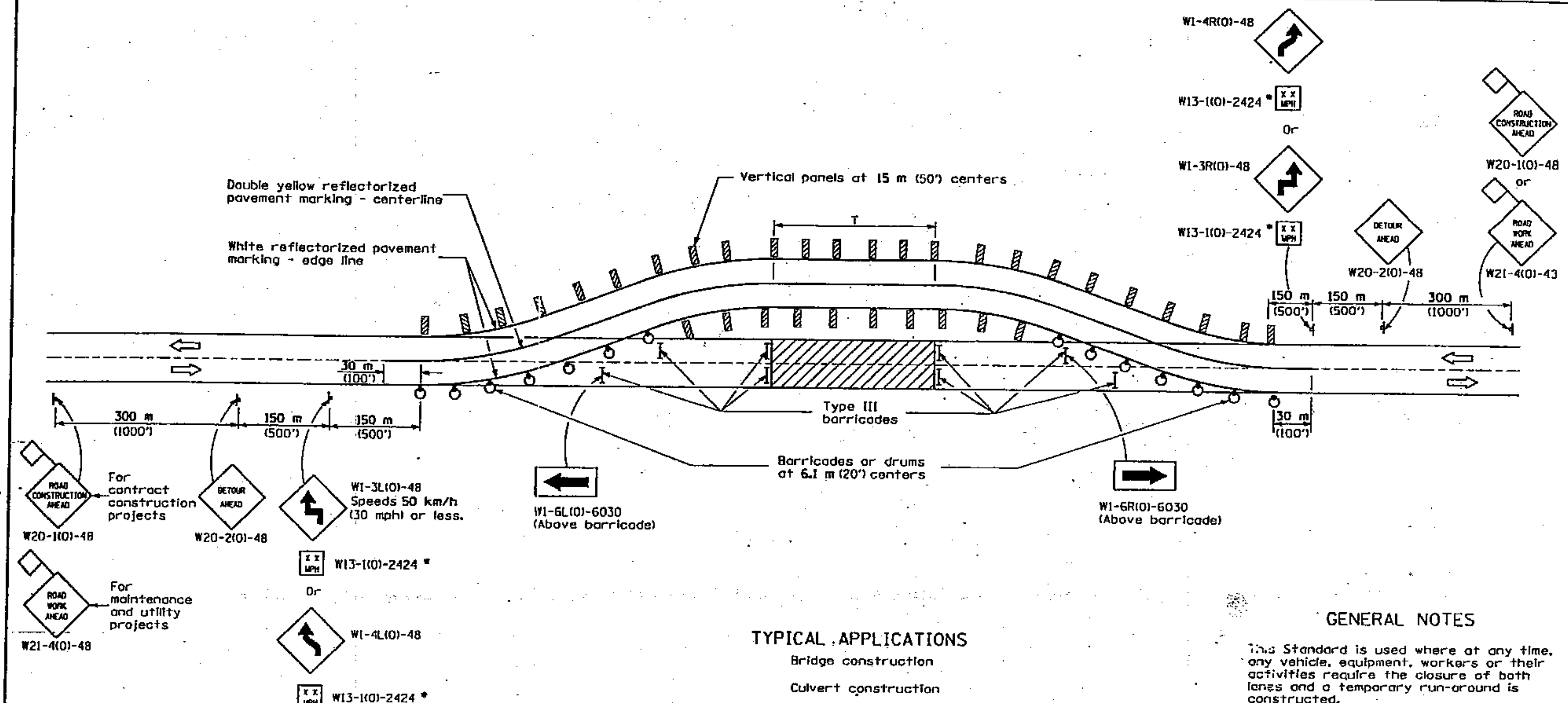
**Table F4**
**Regression Models to Predict Collision with Object s Crash Rates at Non-limited Access Road Workzones**

| Independent Variables | Dependent Variable: Collision with Object Crash Rate (14 sites) | |
|---|---|---|
| | Model 6 | Model 7 |
| Intercept | 0.34 (1.96) | 0.32 (2.69) |
| Crash rate before workzone | 0.30 (1.07) | 0.26 (1.06) |
| 100 = Drums | 0.25 (1.09) | 0.16 (0.86) |
| 103 = Concrete barriers | 0.29 (0.95) | |
| 209 = Workzone speed limit | -0.04 (-0.79) | |
| 501 = Flashing arrow sign | -0.13 (-0.60) | |
| $R^2$ | 0.347 | 0.136 |

$t_{0.05}$ with df = 13, 2.16

# Appendix G

# Using Traffic Control Plans for the Model




## TYPICAL APPLICATIONS

Bridge construction

Culvert construction

## SYMBOLS

- Work area
- Sign
- 450x450 (18x18) Minimum orange flag
- Barricade or drum with monodirectional steady burning light
- Vertical panel
- Type III barricade

## GENERAL NOTES

This Standard is used where at any time, any vehicle, equipment, workers or their activities require the closure of both lanes and a temporary run-around is constructed.

* The advisory speed to be shown below the reverse curve (turn) signs shall be determined at the site and approved by the Engineer.

Type III reflectorized pavement marking tape shall be used for marking the edge lines and centerline on the existing pavement. Either tape or reflectorized pavement marking paint may be used for markings on the paved run-arounds.

All dimensions are in millimeters (inches) unless otherwise shown.

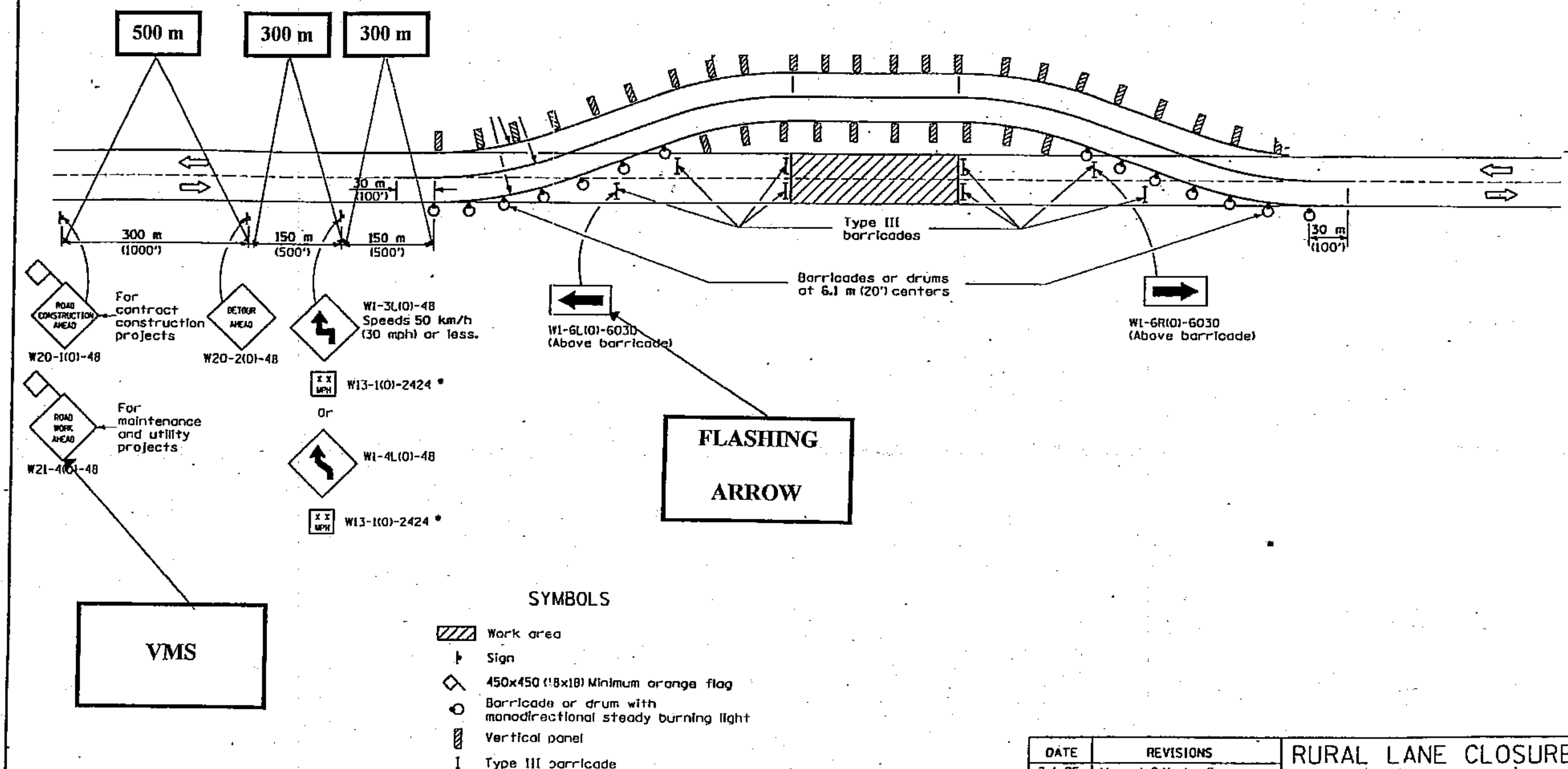
(DN)

| DATE | REVISIONS |
|---|---|
| 2-1-95 | Moved G.N. to Specs. |
| | Revised title. |
| | |
| 6-15-94 | Added Metric. |

**RURAL LANE CLOSURE**
**2-LANE, 2-WAY**
**WITH RUN-AROUND**

F-6.15

## MODIFICATIONS OF THE ADVANCE WARNING SIGNS



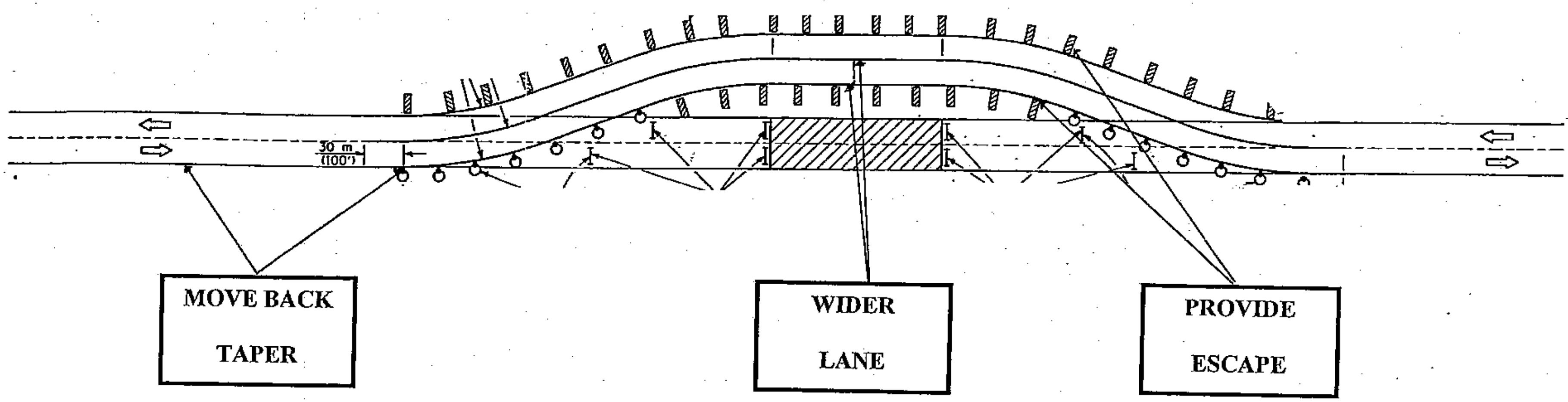

| DATE | REVISIONS |
|---|---|
| 2-1-95 | Moved G.N. to Specs. |
| | Revised title. |
| | |
| 6-15-94 | Added Metric. |
| | Revised notes. |

RURAL LANE CLOSURE
2-LANE, 2-WAY
WITH RUN-AROUND

**STANDARD 2310-8**

F-6.15

## MODIFICATIONS OF THE DELINEATION




SYMBOLS

- Work area
- Sign
- 450x450 (18x18) Minimum orange flag
- Barricade or drum with monodirectional steady burning light
- Vertical panel
- Type III barricade

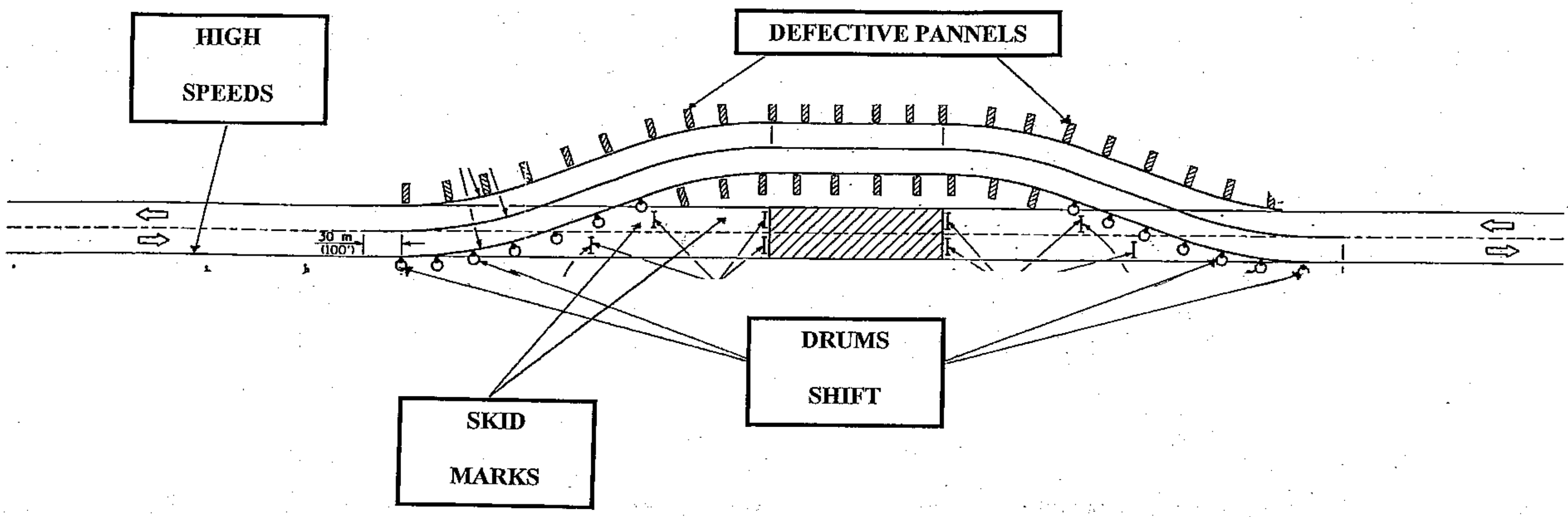
| DATE | REVISIONS |
|---|---|
| 2-1-95 | Moved G.N. to Specs. |
| | Revised title. |
| 6-15-94 | Added Metric. |
| | Revised notes. |

RURAL LANE CLOSURE
2-LANE, 2-WAY
WITH RUN-AROUND

STANDARD 2310-8

F-6.15

## INSPECTION REMARKS




SYMBOLS

- Work area
- Sign
- 450x450 (18x18) Minimum orange flag
- Barricade or drum with monodirectional steady burning light
- Vertical panel
- Type III barricade

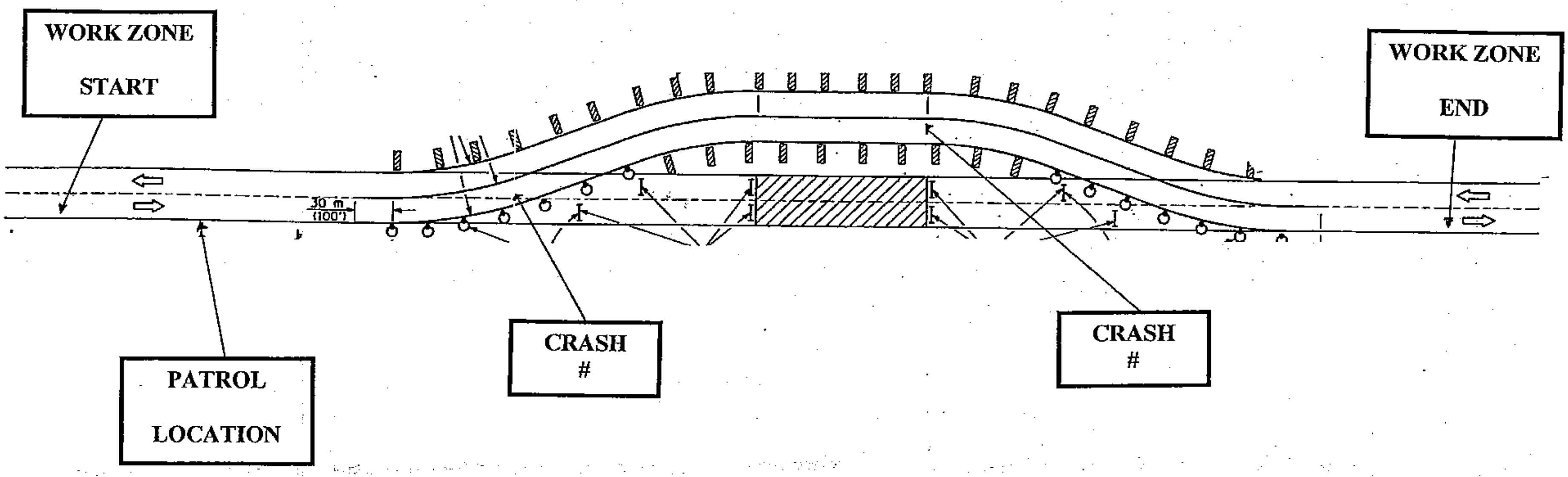
| DATE | REVISIONS |
| --- | --- |
| 2-1-95 | Moved G.N. to Specs. |
| | Revised title. |
| | |
| 6-15-94 | Added Metric. |
| | Revised notes. |

RURAL LANE CLOSURE
2-LANE, 2-WAY
WITH RUN-AROUND

**STANDARD 2310-8**

F-6.15

POLICE REPORTS




SYMBOLS

- Work area
- Sign
- 450x450 (18x18) Minimum orange flag
- Barricade or drum with monodirectional steady burning light
- Vertical panel
- Type III barricade

| DATE | REVISIONS |
|---|---|
| 2-1-95 | Moved G.N. to Specs. |
| | Revised title. |
| | |
| 6-15-94 | Added Metric. |
| | Revised notes. |

RURAL LANE CLOSURE
2-LANE, 2-WAY
WITH RUN-AROUND

**STANDARD 2310-8**

F-6.15