Cleveland State University
Transportation Center
Fenn College of Engineering

TECHNICAL REPORT
CSUTC-TR-08-02

Demonstration of Innovative Techniques for Work Zone Safety Data Analysis (Quarterly Report)

Stephen F. Duffy

OHIO DEPARTMENT OF TRANSPORTATION
QUARTERLY RESEARCH REPORT

For Quarter Ending December 31, 2007

Date Submitted July 6, 2009

Project Title: Demonstration of Innovative Techniques for Work Zone Safety Data Analysis
Research Agency: Cleveland State University
Principal Investigator(s): Stephen F. Duffy

State Job No.: 134332
Agreement No.: 21457
Pooled Fund Study No. (if applicable): ________

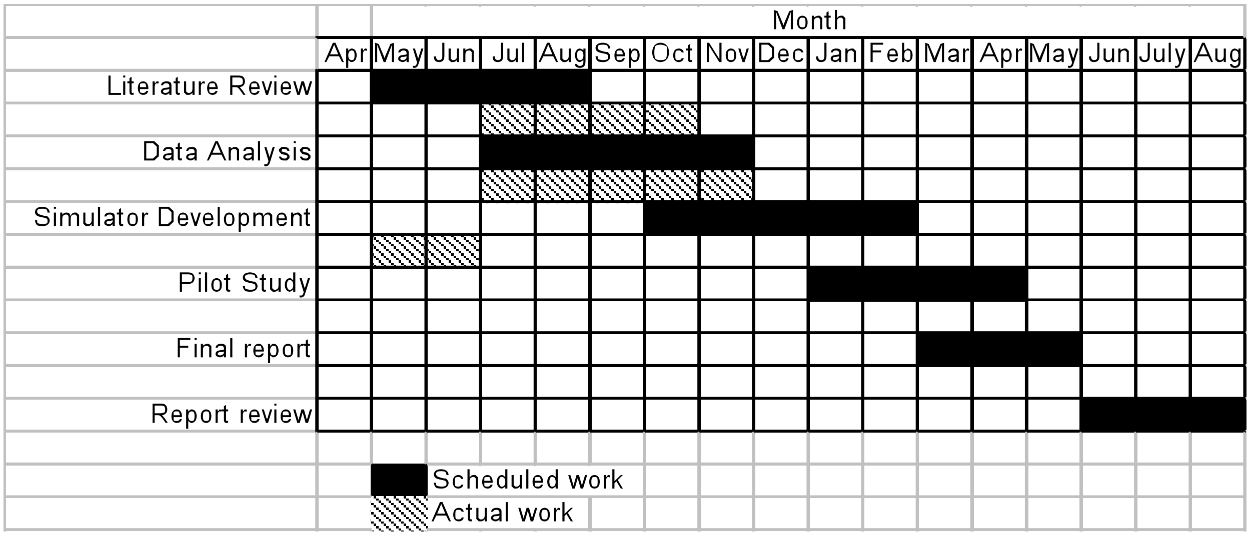
Project Start Date: May 1, 2007
Contract Funds Approved: $61,316 ($62,683 - CSU match)
Project Completion Date: July 1, 2008
Spent To Date: $57,141.86 ($50,725 - CSU match)
% Funds Expended 93% (81% - CSU match)
Work Done 67%
Time Expired 50%

List the Technical Liaisons and other individuals who should receive copies of this report: Monique Evans, Jennifer Gallagher, Omar Abu-Hajar, Karen Pannell, Jill Martindale, Vicky Fout

SUMMARY OF PROGRESS FOR QUARTER:

Schedule of Research Activities

As of December 31, 2007, approximately 67% of the research has been completed. Figure 1 shows the proposed time schedule for each research task and the actual schedule of work completed on each task to date.



	Month																
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug
Literature Review		■	■	■	■												
				▨	▨	▨	▨										
Data Analysis				■	■	■	■	■									
				▨	▨	▨	▨	▨									
Simulator Development							■	■	■	■	■						
		▨	▨														
Pilot Study										■	■	■	■				
Final report												■	■	■			
Report review															■	■	■

■ Scheduled work
▨ Actual work

Figure 1. Schedule of research activities

During the third quarter (the quarter being reported on) the original work schedule called for the development of the simulator scenarios. However, at the end of this third quarter of effort the principle investigator resigned her position at Cleveland State University.

Actual vs. Estimated Expenditures

Figure 2 shows actual vs. estimated expenditures for work completed during the fourth quarter. As of December 31, 2007 approximately 73% of the work was estimated to be completed according to the schedule shown in Figure 1.

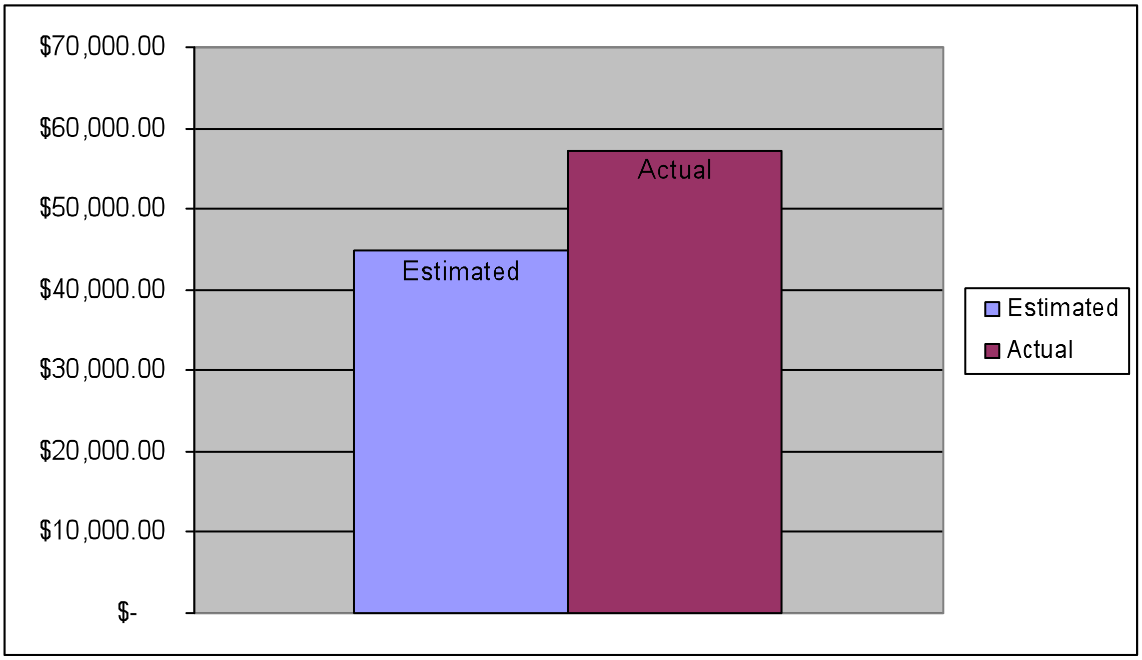


Figure 2. Estimated vs. Actual Expenditures

The estimated ODOT expenditures as of December 31, 2007 were $44,760.68 (calculated as 73% of total budget). Actual ODOT expenditures were $57,141.86.

Percent Completion of Research

At the end of the fourth quarter of this grant approximately 67% of the research has been completed.

Literature Review
The literature review has been completed. The review is presented in Appendix A.

Data Analysis
CSU received the VTTI deliverables. The data includes an excel spreadsheet representing all the relevant variables associated with all 100-Car Study crashes, near-crashes, and incidents that occurred in a work zone.

Simulator Scenarios
Development of simulator scenarios was not complete and will be reported on in the next quarterly report.

PROPOSED WORK FOR NEW QUARTER:

Simulator Scenarios
Simulation scenarios will be finished near term and a detailed overview presented in the next quarterly report.

Validation Study
The validation study will be developed and run based on the findings of the naturalistic data analysis. A qualitative validation analysis will be conducted.

Pilot Study
The pilot study will be developed based on collaboration with ODOT.

IMPLEMENTATION (if any): N/A

PROBLEMS & RECOMMENDED SOLUTIONS (if applicable):

The original contract start date was March 1, 2007. Administrative delays in processing the OPREP contract resulted in an actual work start date of May 5.

Additional administrative delays in processing the VTTI subcontract resulted in a delayed start to the 100-Car data analysis by VTTI researchers. The original due dates for the VTTI portion of the data analysis were July 1 for the first deliverable and July 30 for the second deliverable. Due to the delay, the first deliverable will be received by August 1 and the second deliverable will be received by mid-October.

As a result, the work time schedule and research task order was adjusted to accommodate the administrative delays and prevent downtime by CSU researchers.

As to the departure of Professor Nancy Grugle, Professor Stephen Duffy has proposed to ODOT that he take over the grant as PI in order to finish the research.

EQUIPMENT PURCHASED (if any):

All DriveSafety equipment has been purchased. Driving simulator equipment has been installed and the driving simulation lab was functional as of August 16, 2007.

CONTACTS & MEETINGS:

Dr. Duffy is in contact with Monique Evans regarding the resignation of the principle investigator.

Appendix A

Literature Review

1 Introduction

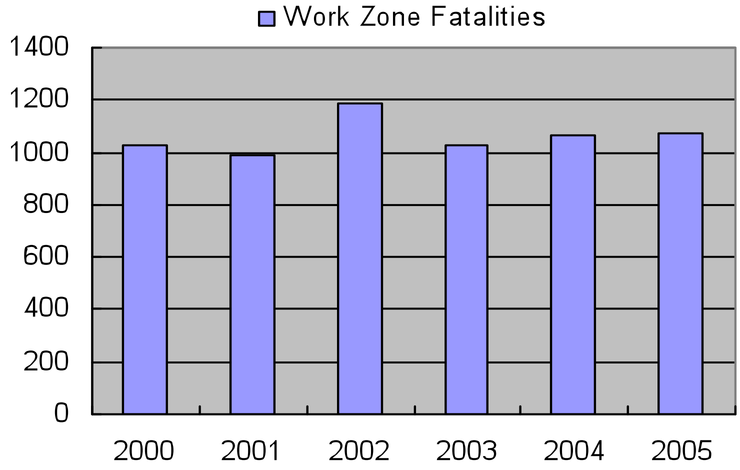
The purpose of this project is twofold - to use a macroergonomic approach to study the causes of work zone crashes, near crashes, and incidents to determine the primary causal factors and to validate a high-fidelity driving simulator (DriveSafety's DS-600c) based on the findings of naturalistic driving data taken in work zones. To address the crash causation portion of the research, CSU will use a macroergonomic approach to analyze naturalistic work zone driving data collected from 100 cars over a one-year period and ODOT historical crash data to identify the subsystem factors (driver, vehicle, organizational, and environmental) that influence work zone safety. In addition, CSU will determine what subsystem interactions play a critical role in work zone safety. To accomplish the second research objective, the pre-crash, near-crash and incident conditions will be replicated in a high-fidelity, fully-immersive simulator and then drivers will be tested under these conditions to determine whether the naturalistic data analysis results can be replicated using the simulator.

1.1 Background

The Nation's infrastructure is in great need of repair. Much of the National Highway System (NHS) is more than 30 years old (Keanan, 2004) and according to the American Society of Civil Engineers' *2005 Report Card*, 34% of America's major roads are in poor or mediocre condition. Coupled with this decline in conditions is an increase in vehicle travel. In Ohio alone, travel increased by 25% from 1990-2003, a statistic that is comparable nationwide. Historical data shows that there were 23,745 miles of roadway improvements underway from 1997 to 2001 and that, on average, motorists drove through one mile of active work zones for every 100 miles driven. In the process of reconstructing our highway system to its optimal condition, the number of temporary and long-term work zones is likely to increase over the next few years (FHWA, 2005). Consequently, as the number of highway work zones increases in the future, more drivers will be exposed to work zones and drivers will encounter work zones more frequently.

1.2 Crash Statistics

In 2005, there were 949 fatal work zone crashes and 1074 fatalities in the nation. Of the 949 fatal crashes, 87% were in construction or maintenance work zones (FARS, 2006). This has grown from 693 in 1997, nearly a 55 percent increase (U.S. Department of Transportation 2003). On average, over 1100 fatalities and over 50,000 injuries occur in work zones every year (See Figure 1). In the year 2005, Ohio work zones alone accounted for 5854 crashes, 1424 injuries, and 20 deaths (ODPS, 2006).



Work Zone Fatalities from 2000 to 2005 (FARS, 2006)

1.3 Work Zone Regulations and Standards

Work zone basic principles and standards for work zone traffic control are set forth in Part 6 of the Manual of Uniform Traffic Control Devices (MUTCD) published by the Federal Highway Administration (FHWA). In addition, 23 CFR 630 Subpart J entitled “Traffic Safety in Highway and Street Work Zones" established a work zone safety and mobility policy to which all states must adhere.

To update and broaden federal regulations on traffic safety in work zones (23 CFR 630 subpart J), the Rule on Work Zone Safety and Mobility was published in 2004. The goal of the rule is to incorporate broader consideration of work zone safety and mobility into work zone policies and procedures as well as to develop a management strategy to minimize the impacts of work zones. The main components of the rule include the following:

- Development and implementation of an overall, agency-level work zone safety and mobility policy to institutionalize work zone processes and procedures.
- Development of agency-level processes and procedures to support policy implementation, including procedures for work zone impacts assessment, analyzing work zone data, training, and process reviews.
- Development of procedures to assess and manage work zone impacts of individual projects. (Rule FAQ, 2004)

1.4 Work Zone Safety Initiatives

In addition to simply adhering to federal and state regulations, work zone safety initiatives at the state and federal level have been established in an effort to improve work zone safety. In response to work zone safety issues, the Federal Highway Administration (FHWA) developed the National Highway Work Zone Safety Program in 1995 with the goal of improving safety and operational efficiency of highway work zones for highway users and workers (Federal Register, 1995). The program has four main components: standardization, compliance, evaluation, and innovation. The program updated work zone safety standards and implemented new standards to include updating federal regulations and the MUTCD as well as developing a methods for testing the crashworthiness of work zone traffic control devices. The compliance portion of the program emphasized improving both contractor compliance with existing guidelines and also improving driver compliance with work zone speed limits and traffic control. The evaluation component focused, in part, on improving the accuracy and sufficiency of work zone crash data. Lastly, the innovation portion of the program was intended to promote the adoption of new and/or improved work zone safety technology as well as to establish an ongoing research program aimed at improving work zone safety. Overall, the program was published as a guide to be used in planning, developing, implementing, and monitoring work zone safety and operational activities nationally.

The Midwest States Smart Work Zone Deployment Initiative (MwSWZDI) was created in 1999 by the states of Iowa, Kansas, Missouri, and Nebraska (http://www.ctre.iastate.edu/smartwz). The name has subsequently changed to Smart Work Zone Deployment Initiative (SWZDI). The goal of the initiative was to research traffic control and safety in work zones. Since its inception, over 50 projects have investigated the effectiveness of work zone-related products and evaluated the application of intelligent transportation system (ITS) devices to traffic control in work zones in order to improve safety and efficiency.

Other smaller scale work zone safety initiatives have been established at the federal, state, and local levels. As an example, the federal government sponsors a work zone safety awareness week and many state and law enforcement agencies collaborate to develop work zone safety awareness campaigns as well. Effective initiatives were also successfully proposed in Ohio during past few years. In 2004, the Ohio Department of Transportation (ODOT) initiated a new crash analysis program designed to identify work zone configurations that contribute to crash problems (National Roadway Safety Award, 2005). The historical and near real-time crash data are used in this program to prevent crashes and detect problems in the field. Through the analysis of crashes using this program, authorities can modify work zones designs accordingly. In addition, ODOT spent $35 million in 2005 to reduce work zone congestion and accidents by conducting more work at night and on weekends, and it also initiated a pilot program to increase law enforcement in work zones statewide in the same year (ODOT, 2006).

2. Work Zone Crash Causation

Despite a significant effort to improve work zone safety and reduce the number and severity of work zone crashes, the precise reasons why work zones crashes occur is still not clear. Much effort has been dedicated to collecting work zone crash data in an attempt to identify or classify the causal factors and then develop appropriate and effective countermeasures. Previous research has cited driver inattention, speed differential, failure to yield, unsafe speed, and following too closely as leading causes of work zone crashes specifically (VTRC, 2002; FHWA, 2005; ODOT, 2005). A 1996 study by Sorock, Ranney, and Lehto (1996) found that 50% to 75% of work zone crashes involved multiple vehicles and the most frequent type of incident was a daytime, rear-end crash. In addition, stopping or slowing in the work zone was the primary pre-crash activity. A 2005 study of work zone accidents at NYSDOT construction projects found that vehicle intrusion into the work area caused the highest percentage of fatal work zone accidents involving construction workers (35.7%) (Mohan and Zech, 2005). However, most of the work zone crash data simply describes the type of crash or pre-crash activity, but does not answer the question “what factors (driver, vehicle, organization, environment or otherwise) increase crashes on roadways where a work zone is present?”

The National Highway Transportation Safety Administration (NHTSA) found that speeding is a contributing factor in 30% of all accidents and fatalities (Fors, 2000). In response to this finding and other similar findings that emphasize the negative effects of speeding in work zones, there has been a significant emphasis on reducing speed and enforcing compliance with posted speed limits in work zones. Police presence or increased law enforcement in the work zone area is considered as one of most effective countermeasures to speed-related crashes in work zones. A 2002 study in Alabama pointed out police presence in work zones was the most effective method to reducing vehicle speeds. Data collected from a total of 254,841 vehicles revealed that the mean speed dropped approximately 17% compared to without police presence. Based on a literature review, survey responses, and interviews, Kamyab et al. (2003) concluded that use of extra law enforcement or police presence in work zones was a common practice in many states and was a significant benefit to work zone safety. A similar survey was conducted in Virginia (Arnold, 2003) and comparable results supported this argument. In 2006, Ohio announced, although the official study has not been conducted yet, they had a 17.7 percent lower crash rate in work zones with increased law enforcement than those without increased law enforcement.

Despite significant emphasis on reducing speed by many state DOTs, there are several problems with this approach. Ha and Nemeth (1995) point out that there is often an overemphasis on speed, when, in fact, driver maneuver is the primary cause of work zone crashes. Law enforcement and researchers often incorrectly conclude that speed was a factor simply because it is included in traditional crash reports (Wang et al., 1996). In support of this assertion, Raub et al. (2001) found that only 5% of work zone crashes are due to excessive speed. An ongoing research project by Cleveland State University found similar results. CSU's results indicated that 43% of all near crashes and crash relevant conflicts involved sudden braking or stopping. Only 2% involved excessive speed.

Furthermore, there is often an unforeseen consequence of reduced speed limits in work zones - increased speed differentials among vehicles. Many studies have concluded that drivers select their own safe speed based on road conditions, regardless of the posted speed. Thus, if the speed is reduced unnecessarily, some drivers will continue at their own perceived safe speed while other drivers will obey the reduced speed limit, thereby creating an unintentional (and dangerous) speed differential. Moreover, typical enforcement of the posted speed in work zones relies on law enforcement presence in a work zone. This often results in a "halo effect" in which drivers slow down in the vicinity of the police, but resume their former speed after a certain distance. It also produces a potentially significant speed differential when a vehicle slows down suddenly at the sight of a police car.
Therefore, the MUTCD and other guidelines suggest NOT reducing speeds in work zones unless it's absolutely necessary to avoid creating large speed differentials. Lastly, studies that emphasize the safety improvements from reduced speeds in work zones typically use metrics such as average reduced speed rather than reduced number of crashes. In fact, a review of the literature found no studies that showed a reduction in crashes as a result of enforced reduced speed in work zones. Therefore, the evidence to support reduced speed in work zones and increased law enforcement of speed in work zones is anecdotal at best.

Future research needs to move beyond speed reduction and focus on ways to reduce other potential causes of work zone crashes (i.e., sudden stopping or slowing, driver inattention, inability to perceive stopped vehicles ahead, etc.).

Interestingly, an in depth analysis of fatal work zone crash sites throughout Texas from February 2003 through April 2004 found that only 8 percent of the crashes classified as occurring in a work zone had a direct influence from the work zone and only 39 percent of were indirectly influenced by the presence of a work zone. Perhaps most importantly, the study concluded that 45 percent of the investigated crashes appeared to have no influence from the work zone. Furthermore, 16 percent of the crashes occurred in work zones in name only (e.g., work zones with only project limit signing) (Schrock, Ullman, Cothron, Kraus, and Voigt, 2004)

In summary, there is still no consensus on the cause of work zone crashes. Moving beyond traditional data collection methods using police crash reports may provide more insight into the causes of work zone crashes.

3. Data Collection Methods and Limitations

Driver behaviors prior to the crash have historically been analyzed based on subjective information from drivers and observers. Surveys have been conducted and narratives from police reports and insurance claims have been studied. However, the usefulness of this information is limited by several factors. First, subjective data is unreliable. Drivers are often unwilling to reveal the true cause of the accident or admit fault to avoid further personal liability. In addition, eyewitness testimony is notoriously inaccurate. Therefore, a critical proportion of work zone crash data is largely unavailable for analysis. Second, databases and police forms often contain incomplete data. For example, some questions that might provide valuable information about the true cause of the accident are simply not asked. Furthermore, the actual driver speed is not usually known or recorded because it can only be estimated after the crash. And finally, data is collected for crashes only. Data on near crashes and incidents is not available in databases simply because the data is never reported to police or insurance companies and thus, is not available for analysis. Historically, work zone safety countermeasures have also been developed based on post-crash data collection (e.g., estimates of driver speed prior to crash).

Although multiple sources of work zone crash data exist, the completeness of these databases is questionable. As Chambless et al. (2002) points out, there is no nationally recognized definition of work zones or work zone-related crashes. Therefore, it is possible that the current work zone crashes are substantially underreported. For example, crasehes that occur in the warning area may not be recognized as part of a work zone. They also found that many states disagreed the FARS database because the actual numbers of work zone crashes were greater than those appeared in the FARS database. According to the study performed by Raub, et al. (2001), 65% of crashes may have been miscoded in Illinois' crash severity database. As a result, the miscoded data would lead to the conclusion that the work zone crashes were more severe than non-work zone crashes. The more important evidence in their study showed that only the 56 reports which carried the "construction zone" code would have showed up in the state database as work zone crashes when, in fact, there were over 103 crashes related to work zones.

In addition, Qi, et al. (2005) identified the fact that many federal databases provide very little additional information about the work zone area in which a crash occurred as a disadvantage of using crash databases to determine causation.

4. Alternative Methods to Studying Work Zone Crash Causation

Due to limitations of existing methods on investigation of crash causation, alternative methods have been introduced to address the knowledge gaps resulting from using existing methods. Several new approaches are described in the following sections.

4.1 Macroergonomic Approach

Macroergonomics is a sociotechnical systems approach to the analysis and design of systems and the application of overall systems design to human factors issues (Hendrick and Kleiner, 2002).

Macroergonomics considers a system's personnel, technological, organizational, and environmental subsystems and their interactions with each other as part of a larger system framework to analyze human factors problems and develop human factors design solutions. Macroergonomics emphasizes congruency between subsystems and the joint optimization of those subsystems. For example, to understand work zone crashes, we must understand that causal factors such as driver behavior and work zone infrastructure are interrelated and cannot be studied in isolation from vehicle technology, roadway conditions, and the driving environment. We must study all aspects of the driving system and the interaction between subsystems (i.e., people, technology, organization, and environment) so that we can understand how their interaction causes unsafe driving. This is referred to as joint causation. Furthermore, we must take all the subsystems into account when designing a solution so that a positive effect on one subsystem does not result in a negative effect on another. This is called joint optimization. It is the understanding of these interactions and the prescription of appropriate interventions based on that understanding that will ultimately lead to a safer and more efficient driving system. Thus, both work zone safety research and the resultant engineering solutions should take a macroergonomic approach. Figure 2 shows how a work zone safety analysis will fit within the macroergonomic framework.

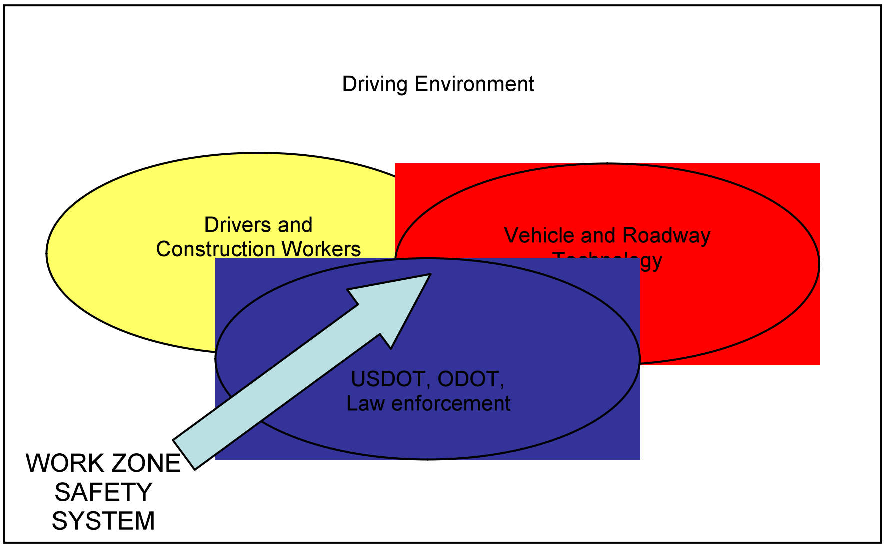


Figure 2. Macroergonomic framework for work zone safety research

Driver factors can be characterized by psychosocial attributes (e.g., risk-taking propensity, age, driving experience, etc.) as well as behaviors (e.g., wireless device use, changing lanes, etc.). Vehicle factors might include vehicle size or type, instrumentation (e.g., ABS brakes, “smart technologies”). The organizational subsystem for driving includes federal and state agencies such as USDOT and ODOT as well as law enforcement agencies. The driving environment includes such factors as road conditions, weather, traffic density, speed limits, etc. A work zone safety system is centered at the intersection of drivers, vehicle and roadway technology, and organizational agencies with all operate in the driving environment. Thus, a macroergonomic approach to driving research will take all aspects of the sociotechnical system into account to develop more effective work zone safety countermeasures.

4.2 Naturalistic Driving Approach

“Naturalistic” driving data includes both vehicular and behavioral data that is collected while driving in an instrumented vehicle under various driving conditions and while performing various daily routines. Data is collected from multiple vehicle sensors and video cameras placed unobtrusively in the vehicle. Drivers are not given driving instructions and experimenters are not present in the vehicle so as to illicit “natural” driving behaviors.

Naturalistic driving studies provide more external validity than laboratory studies and thus, are more generalizable to the driving population and driving conditions at large. Because naturalistic studies can provide data on near-crashes and incidents in addition to crashes, it fills a large gap in the existing driving safety literature. In fact, in a 100-car naturalistic driving study by Virginia Tech Transportation Institute (VTTI), near-crashes occurred 15 times more frequently than crashes (Drive and Stay Alive, 2005). By relying solely on data from crashes, we are neglecting a significant amount of critical safety data including, for example, what factors played a role in the driver’s ability to successfully perform an evasive maneuver rather than crash.

Because current data sources (e.g., crash databases) cannot provide objective data on driver behaviors prior to a crash (for reasons cited above), this research will utilize naturalistic driving data from the VTTI 100-car study obtained during work zone driving to determine what driver behaviors as well as technological, organizational, and environmental factors may cause crashes, near crashes, and incidents. The naturalistic driving data provides videotaped data on driver behaviors, driver distractions, secondary tasks performed while driving, vehicle dynamics, environmental factors, as well as many other factors present at the time of a crash, near-crash, or incident in a work zone. In addition, data is available on near-crashes and incidents that would otherwise have gone unreported and unanalyzed. The naturalistic data is a critical piece of work zone safety data that has not previously been available nor analyzed for work zones specifically.

Data on vehicle technology and environmental conditions is available in the naturalistic data and is available to a limited extent in the ODOT crash database. The naturalistic data provides information on vehicle type, some technological information (e.g., ABS present on vehicle), and vehicle dynamics information prior to and during a crash, near crash or incident. In addition, the weather conditions, time of day, and other environmental factors present during a crash, near crash, or incident are available. The ODOT crash database will provide the information typically available on a police report (e.g., vehicle make and model, weather, time of day, etc.).

Organizational data is available from a variety of sources. This research will consolidate multiple sources of information in an attempt to determine the major causal factors of crashes, near crashes and incidents in work zones using a macroergonomic approach. Once the relevant aspects of the driver, vehicle, organization, and environment have been identified, these factors and their interactions will be considered jointly.

4.3 Driving Simulator Approach

Using a driving simulator to study work zone driving behaviors is a proactive (rather than historically reactive) approach to understanding the driver-related causes of work zone crashes and can provide information about the driver's actions prior to crashes and near-crashes that would be otherwise unavailable. In addition, driving simulators can be utilized to test the effectiveness of recommended safety countermeasures (both infrastructure and driver-related) without putting any drivers at physical risk. Therefore, the simulator provides the ability to perform both basic behavioral driving research as well as applied research to test the effectiveness of safety initiatives. This can include analyzing current work zone jobs in progress to determine if there are potentially dangerous causal factors present that may increase the frequency and/or severity of work zone incidents.

As the prevalence of driving simulators in safety research increases, it is important to understand the differences in driving experience and experimental results between simulators and on-the-road driving. The differences can be described in terms of fidelity and validity. Fidelity is the physical correspondence of the simulator's components, layout, and dynamics with its real world counterpart. The closer a simulator is to real driving in terms of vehicle handling, layout of controls, and realism of graphics, the higher the fidelity of the simulator.

There are two types of validity - relative and absolute.

Absolute Validity: While comparing between driving in the simulator and a real car, using tasks that are as similar as possible in the two environments, if the numerical values between the two systems are the same, then *absolute validity* can be claimed.

Relative Validity: Comparison in the performance differences between experimental conditions in the driving simulator and a real car (Blaauw 1982).

In general, two aspects of simulator validity were assessed in previous research: absolute validity and relative validity (Tornros, 1998; Reed, et al., 1999; Godley, et al., 2002). Absolute validity is dThe absolute validity is established if the numerical values between simulator and real car are the same, whereas the relative validity is claimed when the differences between experimental conditions are in the same direction.

In Lee et al. study (2003), driving performance of older drivers was assessed both on-road driving and simulated driving. They revealed that 65.7% of variability in the on-road driving assessment could be explained by simulated driving assessment. If the simulator sickness participates were removed from analysis, the explainable variability from on-road driving by simulator was 67.1%. Validation studies regarding to drivers' distractions have been conducted in various research. The research about telephone dialing task while driving revealed that generally the variables values were larger in the simulator than on the road even though the same effects were significant both in two methods. Furthermore, the relative validity was established in speed control when the secondary task was performed while driving between the simulator and the on road driving. Other research to compare results of performing in-vehicle information systems while driving among simulators and real word data was conducted by Santos, et al. (2005). However, many inconsistent experimental results were obtained such as mean speed and lateral position.

Generally speaking, absolute validity was not easy to obtain in previous research, while relative validity has been commonly shown. Good relative validity of driving behaviors to driving through a tunnel between simulated road and real road was confirmed (Tornros, 1998). In addition, relative validity was also established for the stop sign approaching speed in a speeding countermeasures study (Godley, et al., 2002). Though the absolute validity is difficult to establish between simulators and real cars, however, relative validity is sufficient for a simulator to be a useful research tool because related research usually aimed to investigate the similar driving behavior patterns, rather than aim to determine numerical measurements (Godley, etl al., 2002).

Compared to enormous simulator-based research as above, applying simulators in work zone safety is rare. Muttart et al. (2007) applied simulator to investigate driver behaviors approaching work zone. They revealed that using cell phone when driving may increase the possibilities of rear-end and sidewipe crashes which are usually seen in work zones. It was attributed to the finding that 30% fewer drivers check rear view mirrors while using a cell phone when driving compared to those without using cell phone. Validation of simulators applied in work zone safety studies is also important as mentioned above. Bella (2004) investigated vehicle speed through work zones by conducting experiments both on real highway work zones and on simulated virtual work zones in simulator. Inconsistently, the mean vehicle speeds through work zones were the same between real highway work zones and simulated virtual work zones, while most studies concluded that the mean speed was higher in the simulator compared to the real car on road (Godley, et al., 2002; Totnros, 1998; Reed, et al., 1999). Finally, the negative results of absolute validity and relative validity were obtained in the research for nighttime work zone devices (McAvoy, et al., 2007).

In sum, applying simulators have some aforementioned advantages, while there are some disadvantages including simulator sickness, physical sensations, and validity (Godley, et al, 2006). In this study, validation of the simulator by naturalistic data will bring benefits to investigate work zone safety research from the long-term viewpoint. In other words, CSU and ODOT can use the fully-immersive driving simulator as a lower-cost tool for extending results from naturalistic driving study to new situations.

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