Detailed Study of Accident Experience in Construction and Maintenance Zones

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The objective of this study was to identify means by which improved traffic control can improve traffic safety in work zones. The accident data base (1982–86) was derived from the coded information stored in the computerized data bank of the Ohio Department of Highway Safety. (The department has since been renamed the Ohio Department of Public Safety.) Coding errors and unreported accidents were recognized as limitations of the data base. Statistical analysis of statewide aggregate data failed to identify cause-and-effect relationships between accident characteristics and traffic control. The study was expanded to include the review of individual accident reports at nine construction sites. This approach proved very effective. The accident reports, which always included a sketch and a description of the event, often indicated that specific traffic control procedures and standards needed to be improved. It has become clear to the researchers that certain types of accidents at a given work zone can suggest specific problems with traffic control plans and/or with the implementation of the plans. Monitoring work zone accidents as they happen is of course the best way to recognize and eliminate problems. In fact, independently from this study, a Work Zone Task Force of the Ohio Department of Transportation that included engineers with intimate knowledge of work zone traffic control practices based on field experience has already recommended improvements in traffic control standards and practices.

Work zones present an abnormal highway environment in that motorists accustomed to a clear, unobstructed roadway are required to recognize and obey an array of instructions conveyed by a wide variety of traffic control devices. They introduce conflict between road users, construction activity, and equipment. The adjacent roadside, usually free of fixed objects, is occupied by warning devices, protective barriers, equipment, and workers. In many instances, the normal roadway capacity is physically reduced by the closing of one or more lanes. The effect of these restrictions is increased delay, which adds to motorist frustration. Work zone traffic control and work zone safety have been a national concern for several years. Reconstruction activities will not diminish in the near future. Driving through work zones will continue to be an everyday driving experience.

There are many well-recognized work-zone-related problems and challenges that are to be faced by transportation departments. The following incomplete list was excerpted from a Federal Highway Administration (FHWA) survey:

- Urban freeway reconstruction;
- The lack of training of contractor personnel;
- The need for specialized equipment, changeable message signs, etc.;
- Motorists driving too fast in work zones;
- Management of both construction and traffic control; and
- The rising number of liability suits.

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NATIONWIDE WORK-ZONE ACCIDENT EXPERIENCE: A LITERATURE REVIEW

Accident Experience

Seven studies were compared in terms of accident experience (*1–7*). Table 1 summarizes the changes in accident experiences during construction. All of these studies show an increase in the accident rate at construction sites. Increases in accident rates during the construction period varied significantly from study to study and very likely depended on specific factors related to traffic, geometry, and environment.

Accident Severity

Ten studies were compared in terms of accident severity (*1–3,5,7–12*). As is illustrated in Table 2, there was a great deal of inconsistency in the findings.

Specific Location of Accidents

The construction zone, which might be several miles long, consists of specific sections. Only four papers discussed the location of accidents within these areas (*2,5,11,13*). These studies involved lane closure situations, except for the Ohio Turnpike study, which included two-way two-lane operation (TWTLO) zones.

Table 3 shows the distribution of accidents at the different areas of the work zone. Once again, there was a lack of consistency in the findings. Clearly, the frequency of accidents in various parts of the work zone varied significantly among the studies because of the different roadway types and traffic controls involved.

Contributing Factors

Seven papers have investigated the factors causing or contributing to work zone accidents (*2,5,7,9,11–13*). The results are summarized in Table 4. These results show more consistency than any of the previous tables, perhaps indicating a relatively uniform use by the reporting offices of the options offered by the crash reporting form.

TABLE 1 Accident Experience During Construction Period

Study	Study Site	% Change in Accident Rate
California (*1*)	California	+21.4 to +7.0
Virginia (2)	Virginia	+119.0
Georgia (*3*)	Georgia	+61.3
Midwest Research Institute (*4*)	Colorado Georgia Michigan Minnesota Ohio New York Washington	+6.8
Ohio (*5*)	Ohio	+7.0
Rouphail (*6*)	Unknown	+88.0
New Mexico (*7*)	New Mexico	+33.0 (Rural Interstate) +17.0 (Federal-Aid Primary) +23.0 (Federal-Aid Secondary)

Specific Findings

Specific findings from past studies varied. The only findings identified by more than one of the past studies are limited to the following:

- The predominant type of accident was rear-end (*5,7,8,11,12*).
- Ineffective attempts were made to reduce speeding problems (*5,8*).
- Improper traffic control was one of the problems in the construction zone (*7,13*).
- Involvement of trucks in accidents at crossovers was significant (*4,13*).

OHIO WORK ZONE ACCIDENT EXPERIENCE (1982–86)

Research Objective

This study had two objectives:

- To identify the nature and seriousness of the work zone safety problem and
- To identify the major cause-and-effect relationships of accidents in work zones and make recommendations.

General Approach and Results

The primary data base (1982–86) was derived from accident reports submitted by law enforcement agencies to the Department of Highway Safety. In the first stage of the study, statewide (i.e., rural state system) accident statistics were reviewed and work zone accident characteristics were compared with statewide accident characteristics. It was observed that

- Work zone accidents were not more severe than all other accidents;
- Work zone accidents were underrepresented at night (i.e., accidents at night were proportionally lower than those during daylight) and under adverse weather conditions;
- Trucks were overrepresented;
- Object and rear-end accidents were overrepresented; and
- Law officers reported "no driver errors" more frequently at work zones.

These observations are based on accidents per time unit as no reliable measures of exposure (e.g., vehicle miles) were available. These results are not counterintuitive and offer no clues to relationship between accidents and traffic control at work zones.

Next, 60 projects were selected for further, more detailed study. The relatively high frequency of accidents on a roadway during the study period and the availability of complete information were the two criteria applied in the selection of this sample. The correlation among accident variables was investigated. Some of the highlights of the findings include (*a*) injury accidents were associated with rear-end and angle accidents, heavy vehicle damage, and multiple vehicle accidents; (*b*) night accidents were object-type accidents, whereas rear-end accidents were frequent during the day, and (*c*) single vehicle accidents were dominant at night whereas two-car accidents were more frequent during daylight. These findings also failed to produce new insights or cause-and-effect relationships.

In the final stage of the project, nine sites were selected as case studies, and the accident reports (OH–1 forms) were studied in detail. Based on the information presented in the accident reports, the authors were able to form some conclusions regarding the operation of most work zones. From some of the specific problems identified at these nine sites, the authors were able to generate recommendations that could improve traffic control at work zones in general.

Data Limitations

Most data bases were subject to two shortcomings: (*a*) uncertainty involving the correctness of the information and (*b*) uncertainty involving the completeness of the data base. Accident records

TABLE 2 Accident Severity Comparison (Change Versus Overall Accident Characteristics)

Study	Severity	
	Fatal	Injury
California (*1*)	Higher	NA[a]
Virginia (*2*)	Higher	Higher
Georgia (*3*)	Higher	Higher
Ohio (*5*)	Higher	NA[a]
New Mexico (*7*)	Same	Same
Graham (*8*)	Same	Same
Flowers (*9*)	Higher	Higher
Richards (*10*)	Low	Low
Kentucky (*11*)	Higher	Higher
Hargroves (*12*)	Lower	Lower

[a]NA = Not Available

derived from police reports are continuously maintained, and because they are computerized, the records are readily accessible. However, problems associated with this data base are well documented and widely recognized (*14*). Problems usually cited included the lack of detail, inaccuracy, and inconsistency in nomenclature and definitions.

When the police reports were reviewed, several recurring errors in coding were observed by comparing statements and sketches with coding. Probably the two most frequent errors in interpretation of definitions given in the Ohio Traffic Accident Procedure Manual were *angle* and *head-on* accidents. Two examples follow that show how these two errors in coding could lead to wrong conclusions.

Example 1

One concern at work zones is the potential conflict between through-traffic and construction vehicles or cars of the crew exiting work zones. Naturally, a high number of angle accidents at freeway work zones would raise suspicion that perhaps this conflict existed at a particular work zone. In fact, the data contained a significant number of angle accidents. However, the review of OH–1 forms indicated that most accidents coded as angle accidents involved cars traveling in the same direction. These accidents should have been properly coded as side-swipe accidents. A significant number of side-swipe accidents would indicate one of two problems: (*a*) an interchange within the work zone is not controlled properly or (*b*) there might be problems with the approach area to lane closure. In summary, the recurring miscoding of side-swipe accidents as angle accidents masked the clues that a certain traffic control problem might exist and gave instead the erroneous indication of another type of problem.

Example 2

One of the most controversial traffic control types at freeway work zones is the temporary TWTLO. The major concern is the potential for head-on collisions, which tend to be severe in terms of injuries. A significant number of head-on collisions in a data base would naturally raise a red flag. In the authors' experience, however, practically all accidents coded as head-on accidents were, in fact, single

TABLE 3 Distribution of Accidents by Location

Location		Study			
		Virginia (*2*)	Ohio Rural (*5*)	Kentucky (*11*)	OhioTurnpike (*13*)
Advance Zone		12.7%	15.9%	5.6%	6.5%
Taper		13.3%	22.5%	7.9%	9.2%
Work Area	Lane Closure or Buffer Area	44.7%	39.1%	54.1%	23.2%
	Construction Area		16.6%		
Ramp		0.0%	3.3%	0.0%	0.0%
Crossover		0.0%	0.0%	0.0%	34.1%
TLTWO		0.0%	0.0%	0.0%	22.2%
Others (Intersection)		29.3%	2.6%	32.4%	4.8%

TABLE 4 Contributing Factors to Construction Zone Accidents

Study	Contributing factors				
	Driver Error	Unsafe Speed	Fail to Yield	Impaired	Follow Too Close
Virginia (*2*)	Yes	No	No	Yes	No
Ohio Rural (*5*)	Yes	Yes	Yes	No	No
New Mexico (*7*)	Yes	No	No	No	Yes
Flowers (*9*)	Yes	No	No	No	No
Kentucky (*11*)	Yes	Yes	No	Yes	No
Hargroves (*12*)	Yes	No	No	No	No
Ohio Turnpike (*13*)	Yes	Yes	No	No	No

vehicle accidents. The head-on definition is assumed by officers to refer to the area of the vehicle that was damaged. In one extreme case, an object fell from a truck and hit the windshield of a car. This accident was also coded as a head-on collision. The potential for misleading the analysts by consistent and frequent coding errors is quite real.

A detailed review of all construction accident reports and an examination of the coding led to the correction of miscoded data. As shown in Table 5, the angle, head-on, parked-motor-vehicle, and other-object accident categories have a significant number of recoded accidents. Of the 810 work zone accidents at the nine sites, 124 cases (15.3 percent) were judged to have been miscoded.

To compensate for the identified coding errors, these accident reports were reanalyzed and corrected as identified. The result is shown in Table 6. Another well-recognized shortcoming of any data base derived from accident reports is the widespread problem of underreporting. In Ohio, evidence was presented by a Northeastern Ohio Trauma Study (*15*). Hospital records of 882 injuries were compared with accident reports. The findings were quite startling. Only 55 percent of the injury-causing accidents were actually

TABLE 5 Accident Distribution for Accident Types by Construction Period

Accident Type	Construction Period			
	Before	During (Original)	During (Revise)	After
Head-On	9	24	7	7
Rear-End	68	175	164	92
Backing	1	7	8	11
Side-Swipe (Meeting)	1	4	1	2
Side-Swipe (Passing)	59	115	136	50
Angle	19	65	39	65
Parked Motor Vehicle	7	10	21	11
Pedestrian	2	6	6	1
Animal	35	29	30	54
Train	0	0	0	0
Pedalcycle	0	0	0	0
Other Non-M.V.	0	0	0	0
Fixed-Object	107	221	201	130
Other-Object	13	47	106	25
Fall From or In Vehicle	1	4	0	6
Overturning	10	25	24	6
Other Non-Collision	51	78	67	50
Total	**383**	**810**	**810**	**510**

TABLE 6 Distribution of Miscoded Data by Accident Types

From\To		O[a]	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Head-On:	A	24	6	0	0	0	0	1	0	0	0	0	0	0	0	17	0	0	0
Rear-End:	B	175	0	161	1	0	4	0	8	0	0	0	0	0	0	1	0	0	0
Backing:	C	7	0	0	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Sideswipe (Meeting):	D	4	1	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0
Sideswipe (Passing):	E	115	0	1	0	0	107	0	3	0	0	0	0	0	1	3	0	0	0
Angle:	F	65	0	1	0	0	23	38	1	0	0	0	0	0	1	1	0	0	0
Parked Motor Veh.:	G	10	0	0	0	0	0	0	9	0	0	0	0	0	0	1	0	0	0
Pedestrian:	H	6	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0
Animal:	I	29	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	0
Train:	J	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pedalcycle:	K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Non-M.V.:	L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fixed-Object:	M	221	0	1	0	0	0	0	0	0	0	0	0	0	193	22	0	0	5
Other-Object:	N	47	0	0	0	0	0	0	0	0	1	0	0	0	0	46	0	0	0
Fall From or In Vehicle:	O	4	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	1	0
Overturning:	P	25	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	23	1
Other Non-Collision:	Q	78	0	0	0	0	0	0	0	0	0	0	0	0	5	12	0	0	61
Revised Data		810	7	164	8	1	136	39	21	6	30	0	0	0	201	106	0	24	67

[a] O stands for original data

reported. When the injury involved children under the age of 16, only 28 percent of the crashes were reported as traffic accidents.

By reviewing 18 research reports from many different countries, Hauer and Hakkert found that the problem is worldwide (*14*). They estimated that on the average, police reports miss perhaps 20 percent of the crashes that resulted in injuries requiring hospitalization. Hauer and Hakkert suggested that as much as 50 percent of the other injury crashes might go unreported. The large percentages of unreported crashes make uncertain all quantitative conclusions based on such an incomplete data base.

It would be convenient to assume that the probability of crashes going unreported at different locations and at different times is constant. In that case, statements based on the differences between two data sets would still be valid. However, there is no evidence to justify this assumption.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are organized into two sections. Each section attempts to respond to one of the two objectives of this study.

Identify the Nature and Seriousness of the Work Zone Safety Problem

In 1988, over 74,000 accidents were reported in Ohio on the Rural State System. Of these accidents, 1.72 percent were coded as work zone accidents. (The latest available data are for 1993, for which 1.8 percent of the accidents were coded as work zone accidents.) There is no baseline available by which one could judge the seriousness of the work zone safety problem, as represented by this 1.72 percent proportion. Work zone accidents show a trend that is different from the trend shown by all accidents on the Rural State System. Although all accidents increased from 1984 to 1988, work zone accidents decreased. Assuming that reconstruction and maintenance activities did not decrease during these years, one might conclude that, although the seriousness of work zone accidents cannot be judged from these numbers, at least some improvement can be claimed.

Injury accidents represent a fairly stable (approximately 34 percent of the total) number of accidents reported on the Ohio Rural State System. Injury accident percentages are consistently lower at work zones by a small margin (31 to 32 percent). In summary, in regard to the question of how serious is the work zone safety problem on the Rural State System in Ohio during the study period, the authors can only say that (*a*) work zone accidents show a trend of decreasing as a percentage of all accidents and (*b*) work zone accidents are slightly less severe than all accidents.

Regarding the nature of work zone accidents, trucks seem to present a special problem at work zones in some situations, as will be discussed later in this paper. The authors can also conclude that accidents at work zones increase more noticeably during daytime than at night. This is to be expected because congestion during peak periods is probably responsible for much of the increase in rear-end accidents.

The authors cannot conclude that work zone accidents decrease at night when compared with before periods. The authors can only conclude that work zone accidents at night decrease in proportion to all work zone accidents. At seven of the nine sites that were investigated in detail, work zone accidents at night actually increased when compared with the before period, but not as much as daytime accidents. This is significant because it might be more feasible to reduce nighttime accidents with proper delineation than to eliminate congestion (which contributes to the increase of daytime accidents).

Identify Major Cause-and-Effect Relationships of Accidents in Work Zones and Make Recommendations

By careful analysis of the information recorded on the OH–1 form by the law enforcement officers at the site, the authors have attempted to identify specific problems at the nine sites selected as case studies. The problems were different at different sites. At some of the sites, the authors were unable to identify specific problems. All sites had accidents, such as collisions with animals or vehicles catching fire, that were not related to work zone traffic control or construction activities. Discussion of the more significant problems that were identified follow.

Inadequate or Confusing Traffic Control

Case Study 2 2.5 km (7.76 mi), four-lane freeway, pavement repair, resurfacing, shoulder restoration, 1-year duration: Several drivers got into the closed area approaching an exit ramp at night. Uncovered holes in the pavement caused damage to the vehicles and injuries. The traffic control plan calls for a 30.48-m (100-ft) or greater opening at exit ramps; shorter openings required approval by the engineer. No trucks were involved in these accidents.

Traffic control at exit ramps must be reevaluated. It should be made very difficult to enter the closed area before an exit ramp and more easy to recognize the opening to the exit.

Traffic control plans called for a 30.48-m (100-ft) minimum opening at the exit ramps. This may not be sufficient. Drums or barricades are specified to be spaced at 15.24 m (50 ft) on approaching the exit openings. This spacing should be reduced, especially when errant drivers entering the closed area would face open holes in the pavement.

Case Study 8 5.6 km (3.5 mi), four-lane freeway, concrete median divider, pavement repair and resurfacing, guardrail reinstallment, median modification, bridge deck overlies, 1-year duration: The protection provided by the construction barrels appeared to be inadequate as seven accidents were reported resulting from drivers entering the closed lane and driving into holes created by pavement removal. It appears that these drivers intended to exit at the open exit ramps but for some reason entered the closed lanes before they reached the open exit ramp.

As much as possible, it should be made very difficult for drivers to enter closed areas where open holes present serious hazards. Prevention of very damaging liability cases justifies the expenditure of time and effort involved in setting up effective traffic control and temporary barricades, if needed.

Edge Drop or Soft Shoulder

Case Study 2 Edge drop or soft shoulder accidents tended to occur at night. Trucks were involved in four of the seven accidents, including one fatal accident.

Edge drops proved to be very hazardous at Case Study 2. Traffic control plans did not indicate warning signs. This situation must be properly addressed by the traffic control plans.

Traffic Slowdowns

Case Study 1 8.4 km (5.2 mi), four-lane freeway, pavement repair and resurfacing, bridge deck repair, guardrail replacement, 1-year duration: The major problem seemed to be traffic backups resulting in rear-end accidents. The problem vehicles in this situation seemed to be trucks and tractor-trailers.

Traffic signs at work zones should inform drivers of what to expect, where to expect it, and advise them what to do. The traffic control plans did not indicate that drivers approaching this work zone were advised to watch for stopped traffic or traffic slowdowns.

It would be desirable to inform drivers of slow or stopped traffic ahead *when* and *where* it is actually happening. Changeable message signs serve this function very well. Conceivably, truck drivers would also respond to such current information.

Case Study 2 The largest number of accidents were caused by traffic slowdowns. These accidents occurred during daytime, some on wet pavement. Six trucks were involved in these accidents as at-fault drivers. Two were single vehicle accidents: trucks jackknifing due to sudden breaking or running off the road trying to avoid collision with slower traffic.

The *WATCH FOR STOPPED TRAFFIC* signs seemed to be effective at other sites and should always be used when slowdowns are expected.

Lane Changing or Merging

Case Study 3 2.7 km (7.9 mi), six-lane freeway, resurfacing, 1-year duration; *Improper lane change* accidents represented the largest category, with nine accidents. With one exception, these accidents involved trucks, tractor-trailers, or campers.

It is not evident from the sketches that any weakness in the traffic control necessarily contributed to these accidents. They seemed to be caused by errant drivers. These nine accidents are a higher percentage of the work zone accidents (23 percent) than the 15 similar accidents over the same length of roadway adjacent to the work zone (18 percent).

Lane change accidents tended to occur not in the advance area nor at the taper but in the area where one of the three lanes was closed. The problem seemed to be experienced by larger vehicles. It seems that restricting larger vehicles to one of the two open lanes could reduce the problem, assuming that drivers observe the restrictions.

Guardrails

Case Study 2 Guardrails were hit in seven cases, typically in a closed lane situation. The need to provide more delineation to guardrails because of the contrast provided by the highly visible construction barrels is indicated here. Guardrails within work zones may need to be delineated.

Use of Berm as Travel Lane

Case Study 4 12.4 km (7.7 mi), six-lane freeway, resurfacing, 1-year duration: The use of berms to maintain traffic contributed to accidents in different ways: vehicles drifting off the edge lost control; disabled vehicles were parked on the berm; and operaton of ramps was complicated.

The use of the berm as a travel lane led to a variety of problems at this site. This special problem needs to be handled by the traffic control plan, and sufficient attention needs to be paid to the potential problem.

Drivers Who Have Been Drinking Alcohol

Case Study 2 Eight accidents involved drinking drivers, although no such accidents were reported outside the work area at the same site during the same time period. Three of the drinking drivers were truck drivers. Three of the accidents involved a collision with guardrails; in the other accidents, the drivers drifted into the closed area. All but one accident occurred at night.

Case Study 3 Drinking drivers are overrepresented in work zone accidents compared with drivers responsible for accidents outside work zones, and a slightly higher proportion of these accidents, resulted in injuries. All but one vehicle penetrated the work zone area.

Case Study 5 5.6 km (3.5 mi), four-lane freeway, concrete median divider, pavement repair and resurfacing, pavement widening, 20-month duration: Drinking drivers were responsible for all accidents at this site, resulting on one fatal, five injury, and two property-damage-only accidents. However, there is no indication that traffic control at the work zone contributed in any way. The concrete median barrier was involved in several of these accidents, probably contributing to the severity but at the same time preventing potentially more dangerous collisions with opposing traffic.

The problem of drinking drivers was observed at other sites as well. The fatal accident only drew more attention to this issue. This problem, however, cannot be solved by the tools available to Ohio Department of Transportation (ODOT) engineers. The recommendation is to consider identifying the level of drinking driver problems before construction at long-term projects, especially if nighttime work is considered. If the problem is potentially serious, then cooperation of law enforcement agencies might be requested.

Ways To Develop and Implement Means of Improving Work Zone Safety

The case studies described earlier involved reconstruction projects in 1984–85. Since then, significant changes have taken place. In early 1988, ODOT established Work Zone Traffic Control (WZTC) Task Groups to undertake the following tasks:

- Task 1—Develop maintenance of traffic (M/T) policies for construction work zones (CWZs);
- Task 2—Develop M/T standard construction drawings;
- Task 3—Analyze and recommend changes to existing CWZ M/T procedures, practices, and application of TC devices.

These task groups have shown significant progress in a relatively short time. Major accomplishments under Task 1 have been to initiate action that would:

- Create a WZTC engineer in each field district to monitor and control CWZ activities.
- Establish a tentative policy to reduce the speed limit by 16.1 km/hr (10 mi/hr) in construction zones on all urban and rural interstate routes and on all rural multilane highways.
- Establish Corridor Traffic Management planning teams in each district and major urbanized area to address M/T problems created during highway improvements.
- Provide design criteria or performance criteria for the design of CWZ traffic control.

Task 2 has developed new or revised standard construction drawings (SCDs) which will improve WZTC plans and lead to greater uniformity. All SCDs include designer notes to guide the designer. Significant products from Task 3 include:

- A study of TLTWO on rural freeways resulting in recommendations for changes in lane closure practice and median crossover design;
- A revised design for median crossovers at TLTWO;
- A policy on the use of changeable message signs approaching a CWZ area; and
- A study of the problems involved with implementing the use of individual pay items for CWZ, traffic control M/T items, and recommendations to specify such items on selected pilot projects.

INTERPRETATION OF ACCIDENT REPORTING FORMS

By reading the information and studying the sketch prepared by the law enforcement officer, one could often, but by no means always, form an opinion regarding the cause (or more correctly, the major causes) of an accident. During the review of the OH-1 forms, certain common characteristics emerged, as expected:

- The officers almost never volunteered information regarding the quality of traffic control (only one exception was observed).
- The written statements tended not to include statements that clearly indicated a guilty driver.
- Estimated speeds were almost always marked lower than legal speeds even when "unsafe speed" was identified as a contributing driver error.

The officers, quite properly, avoided presenting opinions on subjects that were outside their expertise (i.e., work zone traffic control) or make statements that could not be substantiated by the available evidence. The authors, however, have made an effort to interpret the information and select one of the four factors—traffic control, roadway, driver, or vehicle—as the major contributing factor. This task was made difficult by the fact that there were often secondary contributing factors, such as the combination of darkness and rain, without which the accident probably would not have happened.

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REFERENCES

1. *Construction Zone, Detour and Temporary Connection Accidents.* California Business and Transportation Agency, Department of Public Works, June 1972.
2. Liste, F., R. Bernard, and B. Melvin. *Evaluation of Timber Barricades and Precast Concrete Traffic Barriers for Use in Highway Construction Areas.* Virginia Highway and Transportation Research Council, Sept. 1976.
3. Georgia Department of Transportation, unpublished study.
4. Paulsen, R. J., D. W. Harwood, J. L. Graham, and J. C. Glennon. The Status of Traffic Safety in Highway Construction Zones: An Overview. Presented at 57th Annual Meeting of the Transportation Research Board, Washington, D.C., 1978.
5. Nemeth, Z. A., and D. J. Migletz. Accident Characteristics Before, During, and After Safety Upgrading Projects on Ohio's Rural Interstate System. In *Transportation Research Record 672,* TRB, National Research Council, Washington, D.C., 1978.
6. Rouphail, N., Z. Yang, and J. Fazio. A Comparative Study of Short and Long Term Urban Freeway Work Zones. In *Transportation Research Record 1163,* TRB, National Research Council, Washington, D.C., 1988.
7. Hall, J. W., and V. M. Lorenz. Characteristics of Construction Zone Accidents. In *Transportation Research Record 1230,* TRB, National Research Council, Washington, D.C., 1989.
8. Graham, J. L., R. J. Paulsen, and J. C. Glennon. Accident and Speed Studies in Construction Zones. Report FHWA-RD-77-80. FHWA, U.S. Department of Transportation, 1977.
9. Flowers, R. J., and J. M. Cook. *Accident Severity in Construction Zones.* Texas Transportation Institute, Mar. 1981.
10. Richards, S. H., and M. J. Faulkner. *An Evaluation of Work Zone Traffic Accidents Occurring on Texas Highways in 1977.* Research Report 266–3. Texas Transportation Institute, July 1981.
11. Pigman, J. G., and K. R. Agent. Analysis of Accidents, Construction, and Maintenance Work Zones. Presented at 69th Annual Meeting of the Transportation Research Board, Washington, D.C., 1990.
12. Hargroves, B., and M. Martin. *Vehicle Accidents in Highway Work Zones.* Report FHWA-RD-80-063. FHWA, U.S. Department of Transportation, 1980.
13. Nemeth, Z. A., and A. J. Rathi. Freeway Work Zone Accident Characteristics. *Transportation Quarterly,* Vol. 37, No. 1, Jan. 1983.
14. Hauer, E., and A. S. Hakkert. Extent and Some Implications of Incomplete Accident Reporting. In *Transportation Research Record 1185,* TRB, National Research Council, Washington, D.C., 1988.
15. Barancikand, J. I., and D. Fife. Northeastern Ohio Trauma Study IV. *Accident Analysis and Prevention,* Vol. 17, No. 2, 1985.
16. Nemeth, Z. A. *A Study of Accident Experience in Construction and Maintenance Zones.* Final Report. Ohio Department of Transportation and Federal Highway Administration, 1990.

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