Work Zone Traffic Accidents Involving Traffic Control Devices, Safety Features, and Construction Operations

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There were 496 work zone traffic accidents on New York State Department of Transportation construction projects from 1994 through 1996. These accidents involved impacts with work zone traffic control devices and safety features; construction features, such as pavement bumps and joints; drainage features; excavations and materials; and construction vehicles, equipment, and workers. These items, which include all of the features introduced into the roadway environment by construction activity, represent one-third of all work zone accidents and 37 percent of those involving serious injury. Channelizing devices, arrow panels, signs, and other traffic control devices generally resulted in little harm when impacted. Impact attenuators, both fixed and truck mounted, also performed well. Although portable concrete barriers prevent vehicle intrusions, impacts with barrier are severe events. Barriers must be properly designed and limited to only those locations where they are needed to protect more serious hazards. Construction vehicles, equipment, and workers were involved in over 20 percent of all work zone accidents, resulting in serious injuries. Although intrusions by private vehicles into work spaces are a serious concern, construction vehicles, equipment, and workers in open travel lanes are also a serious concern. Good design of work zone traffic control plans, combined with adequate training and supervision of workers, is essential to control both concerns.

Work zone traffic control has become increasingly complex, as construction program emphasis has shifted from new highway construction to rehabilitating and improving existing roads. Projects may require numerous traffic control devices (TCDs) and other safety features on or adjacent to travel lanes. The congestion inherent in present-day roadwork makes it likely that TCDs and safety features, as well as construction equipment, vehicles, and workers, will be involved in traffic accidents.

Crash-testing research has provided information about how work zone TCDs perform under controlled laboratory conditions. New York State Department of Transportation (NYSDOT) research in the 1980s (*1*,*2*) showed that certain TCDs and safety features can represent a significant hazard when impacted, but that properly designed and installed devices performed well and appeared to present little risk to vehicle occupants and workers. Recent tests in Texas (*3*) reached similar conclusions for Type III barricades and portable sign supports. However, little is known about impacts with TCDs in actual crashes or about accidents involving construction vehicles, equipment, and workers. Information about work zone accidents is scarce, and a "lack of quality data related to the characteristics and conditions existing at the time of the accident" (*4*) is a major obstacle to evaluating work zone safety.

This paper examines work zone traffic accidents involving construction-related items on NYSDOT construction projects. Data were obtained from traffic accident reports submitted under the department's accident reporting system from 1994 through 1996 and represent noncontrolled, "real-life" situations. Items examined include TCDs; safety features; pavement and roadside features, such as bumps, edge drop-offs, excavations, and so forth; and construction vehicles, equipment, and workers. These items represent essentially everything introduced into the highway environment by construction activities.

Examining the frequency and severity of such accidents provides an opportunity to improve the overall level of safety in work zones. Because design, placement, use, and restriction of the items examined are, to a major extent, controlled by those responsible for the traffic control plan and work activities, they can be changed or improved to reduce accident severity and frequency.

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RESEARCH METHODOLOGY

During the 3-year period covered by this study, NYSDOT awarded 1,654 construction contracts for a total of $4.3 billion. These contracts covered all types of highway and bridge work from minor repairs to new construction. Facilities ranged from low-volume streets and rural roads to major urban freeways and encompassed the entire state.

Traffic accident reporting on construction projects is mandated by NYSDOT policy and is required by the standard specifications for certain types of accidents. Specific severity levels trigger the need to report an accident. All accidents within project limits involving a fatality or injury resulting in hospital transport must be reported. In addition, accidents directly involving construction features or operations must be reported regardless of injury. Information is submitted on a standardized report form by project staff and coded into a computerized database in the central office. Data compiled include project description, injuries, various accident descriptors, construction and traffic features, and a brief commentary.

Severity is initially reported as fatal, hospital level, minor, or no injury/unknown, based on observations by project staff, contractor or medical personnel, or witnesses to the accident. Final classification is determined by known information about the accident. Initial classification may thus be changed to fatal or downgraded to minor if a victim is treated and released. The presumption for hospital-level classification is that the victim was admitted to the hospital at least overnight. It is often difficult to obtain information about an accident victim's condition because of privacy considerations and hospital restrictions on release of information. This leads to some blurring of the line between hospital and minor injury categories, and probably results in overestimation of hospital-level injuries.

A preliminary list of work zone traffic accidents was generated for this research by an automated search of the database for each selected feature. Only accidents involving an impact with a device, feature, or worker were considered. Accident commentaries and original report files were reviewed to verify accident categorization injury level, to clarify the involvement of the feature or operation, and to identify extenuating circumstances, like excessive speed. From the final list, relevant parameters were identified and used to generate summary tables.

FEATURES EXAMINED

TCDs used on NYSDOT projects are described in the NYS *Manual on Uniform Traffic Control Devices* (*MUTCD*). The department's standard specifications and standard design details provide additional details for TCDs and safety features. Project traffic control plans and notes in the contract documents contain specific requirements for protecting work operations and workers from traffic, and for identifying vehicles, equipment, and workers.

Traffic Control Devices

Channelizing Devices

Cones, drums, and Type III barricades must meet NYS *MUTCD* requirements, essentially identical to the federal *MUTCD.* Ballast to hold devices in place must be at ground level and containerized to prevent debris from scattering on impact. Recycled-tire ballast rings are permitted for drums. Type III barricades must be frangible or crushable plastic, with collapsible lightweight metal frames also permitted. Metal drums and open-top plastic drums are prohibited.

Signs, Sign Supports, and Related Devices

Rigid sign panels must be at least 1.5 m (5 ft) above pavement. Below 1.5 m, signs must be flexible fabric to reduce the risk of windshield penetration. Fixed sign supports must meet current AASHTO criteria, whereas portable supports must be lightweight, meeting criteria in the standard specifications.

Flashing Arrow Panels

These devices are widely used to mark lane closures on high-speed roadways. Those examined are commercial trailer-mounted 1.2-m by 2.4-m (4-ft by 8-ft) units with the bottom of the panel 2.1 m (7 ft) above pavement. All are powered by diesel-driven generators. Accidents involving vehicle-mounted arrow panels are examined under the vehicle or truck-mounted attenuator categories.

Work Zone Safety Features

Impact Attenuators and Arrester Nets

Impact attenuators include temporary impact attenuator devices (IADs) to protect the ends of portable concrete safety shape barriers (PCBs) or other fixed objects, and truck-mounted attenuators (TMAs) to protect moving work operations and hazards not amenable to other treatments. IADs consist of two commercial units—GREAT CZ and ADIEM—and generic sand barrel arrays. TMAs include various commercial units generally designed for a 72.42-km/h (45-mph) impact speed. Most were mounted on 8165-kg to 9072-kg (18,000-lb to 20,000-lb) trucks, although a few were attached to ballasted trailers or construction equipment, such as rollers. Proprietary arrester nets manufactured by Roadway Safety Systems Inc. are also included in this category.

Portable Concrete Safety Shape Barrier

PCBs are widely used to separate opposing traffic and to separate traffic from long-term work activities and roadside hazards. Proprietary movable PCBs are occasionally used to meet capacity demands on major urban projects. Standard PCBs incorporate the standard MB5 shape and are generally manufactured in 6-m (20-ft) segments, although shorter segments may be used. A strong H-pin joint connection ensures barrier integrity for at least Test Level 3 impacts, with dynamic deflection limited to less than 0.6 m (2 ft). PCB ends must be protected from traffic impacts by various methods, including shielding behind existing barrier, burying in embankment slopes, or using IADs. In some cases, a 6-m (20-ft) sloped end, combined with a flare away from traffic, may be used.

Other Construction Features

Pavement Surface Conditions

Pavement surface conditions include bumps, holes, surface debris, edge drop-offs, and uneven longitudinal joints. Department specifications require the contractor to maintain the pavement surface in suitable condition for safe travel, with specific limitations on uneven joints and edge drop-offs. Signs and warning devices are required whenever these features cannot be eliminated. Drainage features, such as grates, catch-basin inlets, and utility boxes, in or adjacent to the pavement, are also included.

Construction Materials and Debris

Contractors must store materials in safe locations and keep debris from becoming a hazard to traffic. However, materials and debris are occasionally involved in accidents.

Excavations

Temporary barriers, warning fences, channelizing devices, and other means may be used to protect vehicles and pedestrians from excavations near the traveled way. However, errant vehicles and pedestrians occasionally encounter excavations.

Construction Vehicles, Equipment, and Workers

Department requirements to identify and protect vehicles, equipment, and workers include hard hats and high-visibility apparel for workers and warning lights for vehicles in certain situations. Flaggers are required to guide traffic around work activities when barri-

ers or channelizing devices cannot be used. Flaggers also direct construction traffic into and out of the traffic stream.

RESULTS

Channelizing Devices

Table 1 summarizes accidents involving channelizing devices, categorized by device and accident type. Thirty-two accidents were reported, with no fatalities and only four resulting in hospital-level injury. Only eight accidents were simple impacts with a device. The only injury resulting from a direct impact with a device occurred when a cone was dropped from a work vehicle. It broke a car windshield and an occupant received minor lacerations.

In the other 24, the vehicle either first impacted the device, with a secondary collision with another vehicle or roadside object following, or collided with another vehicle or roadside object when a vehicle tried to avoid a device that was in an open travel lane. In 13 secondary-impact accidents, a vehicle struck another vehicle or roadside feature after striking a channelizing device. Three accidents resulted in hospital-level injuries, but the reports indicate that the secondary impacts were much more severe than impacts with the device, and thus are the likely cause of injury. Windshield breakage by the device, leading to a secondary impact, was not reported in any accident.

In 11 avoidance accidents, a vehicle collided with another vehicle or roadside feature after attempting to avoid a channelizing device that had been displaced into the travel lane. Although none resulted in hospital-level injury, seven resulted in minor injuries.

TABLE 1 Channelizing Devices

Device Type	Accident Category	Severity				
		Fatal	Hospital	Minor	No Injury	Total
Cone	1	0	0	1[a]	1	2
	2	0	0	1	1	2
	3	0	0	2	2	4
	4	0	0	0	1	1
Drums	1	0	1[b]	0	1	2
	2	0	2	3	2	7
	3	0	0	2	1	3
	4	0	0	3	0	3
	5	0	0	0	1	1
Type III	1	0	0	0	3	3
	2	0	1[c]	1	2	4
Subtotal	1,5	0	1	1	6	8
	2	0	3	5	5	13
	3	0	0	4	3	7
	4	0	0	3	1	4
Total		0	4	13	15	32

[a]Vehicle entered work zone where cones were being picked up from contractor's truck. Worker in truck lost balance and dropped cone on vehicle windshield, which broke. Passenger received minor cuts.
[b]Worker injury - hit by drum displaced by vehicle or possibly vehicle itself.
[c]Vehicle struck drums, Type III barricade, arrow panel, and other roadside features. Driver received hospital level injury. A worker struck by debris received minor injury.

Accident Category:

1. Device in normal position - no secondary impact involved.
2. Device in normal position - secondary impact on roadside or another vehicle.
3. Device in travel lane - avoidance collision with another vehicle.
4. Device in travel lane - avoidance maneuver resulting in secondary impact or run-off-road accident.
5. Device in travel lane - device struck.

A related concern is injury to workers struck by a channelizing device after vehicle impacts. Two such incidents are included. In one, a worker received minor injuries when struck by debris after a vehicle hit drums, Type IIIs, and an arrow panel. In the other, a worker received serious head injuries when a vehicle entered a closed lane at a nighttime work operation. The accident was not witnessed, and it is unclear whether the worker was struck by a displaced drum or by the vehicle's mirror or other protrusion.

Signs and Flashing-Arrow Panels

Signs and Similar Devices

Twenty-two accidents involving signs and similar devices are summarized in Table 2. One accident—with no injury—involved a flag tree. Two others—also with no injuries—involved signs mounted atop Type III barricades placed in the travel lane at road closures. The other 19 accidents involved signs on portable and fixed supports. Usually, the accident report provided little or no description of the device, so these accidents are not identified by sign or support type, except as discussed below. The accidents are categorized by location of the sign—in a travel lane, on the roadside adjacent to the travel lanes, or having fallen onto a vehicle—and by presence or absence of secondary impacts.

One fatal accident involved a construction sign mounted on a breakaway flanged-channel post at the shoulder edge. A vehicle left the travel lane, struck the sign structure, then struck a breakaway luminaire support, and finally overturned, killing two occupants. There is no indication that impact with the small sign support affected the severe outcome of this accident.

Two accidents resulted in hospital-level injuries. In one, a vehicle struck a portable sign on the shoulder. The sign broke the windshield, and the driver suffered internal injuries. In the other, a portable sign blew down, leaning across a concrete barrier into the travel lane. A vehicle struck the sign, breaking the windshield, with the driver receiving facial lacerations. There were no other reports of broken windshields from sign impacts.

Six additional accidents involved signs falling or blowing over onto vehicles as they passed. None resulted in injuries.

One minor worker injury occurred when a construction sign fell into an open lane while it was being erected. The sign was struck by a vehicle, and then hit a worker.

Flashing-Arrow Panels

Nineteen accidents involving trailer-mounted arrow panels are summarized in Table 2. In the only fatality, a stolen vehicle, traveling at an estimated 161 km/h (100 mph), impacted an arrow panel at the start of a lane closure and subsequently overturned. All three of the hospital-level injuries also involved extenuating circumstances. Two were high-speed impacts with the arrow panel—one during a police pursuit—and both involved secondary impacts with formidable roadside features. In the third, the driver suffered a stroke before impact, and the hospitalization resulted from the stroke rather than the impact.

Two accidents involved only minor injuries, and 13 involved none. Two of these were hit-and-run accidents.

Impact Attenuators, Arrester Nets, and Portable Concrete Safety Shape Barrier

Impact Attenuators and Arrester Nets

Table 3 summarizes accidents involving several types of impact attenuators. Sand barrels, GREAT CZ, and ADIEM installations

TABLE 2 Signs and Similar Devices

Accident Category	Device Location	Severity				
		Fatal	Hospital	Minor	No Injury	Total
Signs						
No Secondary Impact	Roadside	0	1	1	5	7
	Open Lane	0	1	1	2	4
	Fell onto vehicle	0	0	0	6	6
Secondary Impact	Roadside	1	0	1	2	4
	Open Lane	0	0	1	0	1
Total		1	2	4	15	22
Flashing Arrow Panels						
No Secondary Impact		1[a]	0	1	11	13
Secondary Impact		0	3[b]	1	2	6
Total		1	3	2	13	19

[a]Pre-impact speed reported at 100 mph -- secondary overturn.
[b]Extenuating circumstances involved in all three -- see text.

TABLE 3 Impact Attenuators and Arrester Nets

Accident Type	Severity				
	Fatal	Hospital	Minor	No Injury/ Hit and Run	Total
Attenuators and Arrestor Nets					
Inertial-Sand Barrels	0	2	1	44	47
Great CZ™	0	1	0	7	8
ADIEM	0	0	2	0	2
Truck Mounted-Rear End Hit	0	6	7	8	21
Truck Mounted-Side Hit	0	0	1	2	3
Arrestor Nets	0	1	0	4	5
Total	0	10	11	65	86
Portable Concrete Barrier					
No Secondary Impact	1	3	2	16	22
Overturn After CB Impact	0	2	1	2	5
Primary Impact on CB					
Other Vehicle Secondary	2	2	1	3	8
Other Object Secondary	3	1	0	3	7
Secondary Impact on CB					
Other Vehicle Primary	0	8	1	6	15
Other Object Primary	0	0	4	2	6
Total	6	16	9	32	63

deployed to protect the ends of portable concrete barriers were generally very effective in preventing serious injuries.

Two hospital-level injury accidents were reported on sand barrels, but the injuries did not appear serious. In one, a vehicle struck the barrels and overturned after first striking another vehicle. Forty-four sand barrel accidents were hit-and-run incidents, with the vehicle leaving the scene unassisted. It is assumed that injuries in those accidents, if any, were very minor.

Seven of the eight accidents involving GREAT CZ were hit-and-run incidents, assumed to be very minor. One accident involving a small car resulted in an unspecified hospital-level injury.

Only two hits were reported on ADIEM. In both cases, tractor trailers penetrated the full length of the terminal and struck a portable concrete barrier and bridge rail, with one subsequently overturning. In both cases, the drivers received minor injuries.

Twenty-one impacts were reported on the rear of TMAs, including six with hospital-level injuries. However, in three of those accidents, injuries were reportedly not serious. One of these involved a motorcycle and one a large van carrying prisoners. Two accidents with serious injuries involved impacts by small cars, one a corner impact on a parked TMA. The third serious injury occurred when a van impacted the TMA, and its unrestrained driver struck the windshield. Three additional impacts were reported in which vehicles struck the side of shadow vehicles equipped with TMAs, none resulting in serious injury.

Five hits on arrester nets were reported. In four, the vehicles were prevented from entering the work space. However, in one of these accidents, the intruding vehicle deflected the net into a vehicle parked 6 m (20 ft) behind the net. A security guard in the parked vehicle sustained hospital-level injury. In the fifth accident, an improperly installed energy-absorbing unit failed, and the vehicle drove through the net and 0.8 km (0.5 mi) into the closed roadway before being stopped by police.

Portable Concrete Safety Shape Barrier

Sixty-three accidents involving PCBs are summarized in Table 3. They are categorized into four groups, with the last two groups, which involved collisions with something besides the barrier, subdivided into Vehicle and Other Object categories. Six PCB accidents resulted in fatal injuries, and 16 others in hospital-level injuries. However,

three of the six fatalities involved motorcycles, and two others involved vehicles redirecting from a PCB impact on the right side of the road, crossing the median, and striking oncoming traffic.

Over half of these accidents involved some form of secondary impact, either before or after the vehicle struck the PCB. Only 22 accidents involved no secondary impact. Nearly all of these involved minor or no injuries (including hit-and-run accidents), with only three resulting in hospital-level injury, and one motorcycle fatality. In addition to these 22 accidents with no secondary collisions, 5 others resulted in vehicle rollovers, with no secondary collisions. Two resulted in hospital-level injuries.

In 15 other accidents, a vehicle first struck the PCB, then collided with another vehicle or object. Severity for these accidents was classified by the most serious injury in the entire accident, since the cause-effect relationship among the PCB, the secondary events, and the injuries cannot be determined. Five of these accidents resulted in fatalities, two involving secondary cross-median collisions with other vehicles, one in which a sport utility vehicle penetrated a PCB and collided with an excavation, and two motorcycle accidents involving secondary impacts after striking the PCB. In one of these motorcycle accidents, contact with an uneven longitudinal pavement joint may have occurred before impact with the barrier.

In 21 other accidents, a vehicle struck a PCB after colliding with another vehicle or object. In these accidents, severity was classified according to the most severe injury in the vehicle striking the PCB. Eight of the 15 PCB accidents involving primary collisions with other vehicles resulted in hospital-level injuries in the vehicles that subsequently struck the PCB. However, the extent to which the PCB contributed to these injuries is uncertain.

Impacts on sloped PCB ends is a serious concern because of the potential for vaulting and severe rollovers. Only three such events were identified in these 63 accidents. In two, vehicles came to rest on sloped ends after other impacts, and it does not appear that the ends contributed to the seriousness of the accident. In the third, a high-speed automobile ramped up a sloped end, struck a bridge rail behind the PCB, and overturned, resulting in serious injury to the occupants. Because of the very high speed impact, it cannot be concluded whether any end treatment would have prevented serious injuries.

In addition to the five accidents in which vehicles overturned after striking PCBs, four accidents involving secondary collisions resulted in overturns. In two, tractor trailers struck ADIEM end terminals, ran up onto the PCB itself, and overturned. Another involved a sloped PCB end as well. Overturns on redirecting from the PCB itself were thus relatively infrequent—only six cases if terminal impacts are not considered.

One accident involved proprietary movable concrete barriers. A hospital-level injury resulted when a barrier was struck after two vehicles collided.

Construction and Pavement Features

Sixty-five accidents involving pavement and construction features are summarized in Table 4, including 50 vehicular and 15 pedestrian accidents. Just over half the vehicular accidents involved pavement

TABLE 4 Accidents Involving Construction and Pavement Features

Pavement/Construction Feature	Severity				
	Fatal	Hospital	Minor	No Injury	Total
Vehicular Accidents					
Pavement Feature[a]					
Primary Impact	0	1	5	9	15
Secondary Impact[b]	0[c]	3	2	3	8[c]
Avoidance Impact	0	1	1	2	4
Grate-Drop Inlet-Manhole	0	1	2	4	7
Construction Material/Debris	0	3	2	3	8
Excavation	0	3	1	4	8
Pedestrian Accidents					
Construction Material/Debris	0	3	3	0	6
Excavation	0	0	5	1	6
Trip & Fall-No Features	0	0	3	0	3
Total	0	15	24	26	65

[a]Pavement features include bumps, holes, and rough surfaces, milled surfaces, and edge dropoffs.
[b]Secondary impacts are impacts after the vehicle encountered the pavement feature.
[c]Information received subsequent to the initial accident report indicates that one fatal accident where a motorcycle impacted Portable Concrete Barrier may have involved an uneven longitudinal pavement joint. That accident is recorded in Table 3.

features—bumps, holes, uneven joints, and so forth. In 15 accidents in which no secondary impact occurred, only 1 resulted in hospital-level injury, when a motorcycle overturned on rough pavement. Most of these accidents resulted in vehicle damage only. In 12 of the 27 pavement-related accidents, a secondary impact or avoidance accident took place. In three of the secondary collisions, hospital-level injuries occurred. Avoidance impacts occurred when vehicles slowed or swerved to avoid bumps or other features.

The 27 pavement-feature accidents included 6 accidents involving pavement edge drop-offs or uneven longitudinal joints. One resulted in injury when the vehicle ran off the road and overturned, with the driver hospitalized for minor injuries. (According to information received after the initial accident report, an uneven pavement joint may have been a factor in one fatal accident where a motorcycle struck a portable concrete barrier. This accident is classified as a PCB accident.)

Seven accidents involved impacts with drainage features in or adjacent to the pavement. One hospital-level injury occurred when a vehicle struck a dislodged drainage frame, overturned, and caught fire. The other six involved no secondary events, and resulted in minor or no injuries.

Construction material or debris was involved in eight vehicular accidents. Only one involved a secondary event, with the vehicle striking trees and overturning after striking construction materials on the roadside, resulting in a hospital-level injury. In another hospital-level accident, a worker was struck by a plywood sandblast debris shield dislodged by a truck impact. Other accidents in this group included vehicles striking construction materials stored along the roadway, as well as construction debris on the pavement or falling onto passing vehicles.

In eight accidents, vehicles entered roadside excavations, with three resulting in hospital-level injuries. However, in one, a collision with another vehicle occurred before the vehicle backed into an excavation.

Fifteen accidents involving pedestrians, and pavement or construction features were reported. Nearly all involved tripping/falling incidents. Only three resulted in hospital-level injuries.

Construction Vehicles and Equipment

Table 5 summarizes 99 accidents involving collisions between construction vehicles and the traveling public, both vehicles and pedestrians, and 65 accidents involving collisions between private vehicles and construction equipment. These accidents occurred both in work spaces and other areas not intended for traffic, as well as in open travel lanes. Not included here are accidents involving construction vehicles colliding with other construction vehicles or equipment, or with pedestrian workers.

Construction Vehicles

Accidents are categorized according to 11 combinations of accident type and location. Collisions with work vehicles entering, exiting, or crossing open travel lanes were the most frequent, with 24 occurrences, including 11 hospital-level injuries. Two-thirds of these accidents involved large trucks, which relate to their reduced maneuverability and acceleration/deceleration ability. Other frequent accident types are work space intrusions, collisions between vehicles and work vehicles at the travel space-work space boundary, and accidents during setup and takedown.

Twelve accidents resulted in injuries to workers in construction vehicles, including seven hospital-level injuries. Two-thirds of all worker injuries and nearly two-thirds of worker hospital-level injuries involved small work vehicles.

Only one accident involved a nonworker pedestrian struck by a work vehicle—a van operated by a construction employee backed into an elderly pedestrian in a crosswalk within a lane closure. Three other backing accidents involved work vehicles and public vehicles.

Accident Types 1, 2, and 9 represent so-called intrusion accidents in which vehicles entered a stationary work space defined by traffic control devices, or a temporary work space defined by the work vehicle. These accidents accounted for 10 of the 28 hospital-level injuries, and 37 of the 99 total work vehicle accidents, or just over one-third of each. However, five of the seven hospital-level worker injuries occurred in intrusion accidents.

Construction Equipment

None of the construction equipment accidents involved pedestrians. However, three resulted in injuries to worker operators—one hospital-level and two minor. Accidents involving equipment in a defined work space were most frequent, followed by flagger-controlled sites, roadside, and buffer space collisions.

Three fatal accidents occurred. Two were work space intrusions during night operations, one involving a roller and the other a pavement breaker. The other fatality occurred when a vehicle disregarded flagger instructions and struck the rear of a paver.

Two out of 3 fatalities, 8 of 16 hospital-level injuries, and 31 of 65 total accidents were intrusion accidents, in either stationary work space or temporary work spaces defined by work vehicles or equipment.

All four hospital-level accidents categorized as Type 6—equipment traveling in open travel lanes—occurred during night operations.

Accidents Involving Workers and Flaggers

Table 6 summarizes 45 accidents involving vehicles or debris from vehicles striking pedestrian workers or flaggers. Five resulted in worker fatalities, and 21 others in hospital-level injury.

Pedestrian worker accidents are categorized by location. Half of these accidents and half of the serious injuries (fatal and hospital) occurred in defined work spaces or at the boundary between work and travel space. The other half occurred in travel lanes or on the roadside. Accidents involving flaggers represent more than one-third of the total and serious injury accidents. Because flaggers control traffic behavior and provide directions to drivers, all accidents involving flaggers struck by vehicles are considered to be intrusion accidents.

DISCUSSION OF RESULTS

Table 7 summarizes accidents for the features discussed in the previous sections and summarizes all work zone traffic accidents on department projects over the same period.

The first three categories include traffic control devices, which accounted for less than 5 percent of all work zone accidents and about 8 percent of those resulting in serious injury. Other than two accidents involving signs penetrating windshields, it appears that all other serious injuries were related to either extremely high speeds

TABLE 5 Accidents Involving Construction Vehicles and Equipment

Accident by Type/Location	Severity				
	Fatal	Hospital	Minor	No Injury	Total
Vehicle Accidents					
1	0	7	3	9	19
2	0	2	1	2	5
3	0	3	3	8	14
4	0	11	4	9	24
5	0	2	1	6	9
6	0	1	1	2	4
7	0	0	1	3	4
8	0	1	1	3	5
9	0	1	8	4	13
10	0	0	1	1	2
11	0	0	0	0	0
Total	0	28	24	47	99
Equipment Accidents					
1	2	4	6	8	20
2	0	4	3	1	8
3	0	1	1	6	8
4	0	0	0	4	4
5	1	3	2	3	9
6	0	4	0	2	6
7	0	0	2	5	7
8	0	0	0	0	0
9	0	0	0	0	0
10	0	0	0	0	0
11	0	0	1	2	3
Total	3	16	15	31	65

1- Vehicle intruded into work space, struck work vehicle.
2- Vehicle struck work vehicle on roadside.
3- Vehicle in travel space, work vehicle in work space, inadequate buffer space resulted in collision.
4- Work vehicle entering/exiting/crossing travel lanes.
5- Flagger control site - vehicle or work vehicle failed to comply.
6- Multi-vehicle collision in travel space (not moving operation).
7- Work vehicle backing - struck vehicle/pedestrian.
8- Vehicle crossing work space for driveway access collides with work vehicle.
9- Vehicle/work vehicle collision during traffic control setup/takedown.
10- Other/unidentified.
11- Moving operation in travel lanes.

TABLE 6 Accidents Involving Flaggers and Workers

Accident Type	Severity				
	Fatal	Hospital	Minor	No Injury	Total
Workers					
In Travel Lanes	2	4	3	1	10
In Work Space	0	6	5	0	11
On Roadside	1	1	2	0	4
Boundary-Travel/Work Space	0	2	1	0	3
Subtotal	3	13	11	1	28
Flaggers	2	8	6	1	17
Total	5	21	17	2	45

or secondary/avoidance impacts and are *not* attributable to the design of the devices. It is suspected that these devices are involved in many additional incidents that are not reported because the severity was minor. In other cases, these devices may have been involved in reported accidents but not mentioned because their involvement was considered inconsequential by those preparing the accident report.

Impact attenuators and arrester nets were involved in just over 5 percent of all work accidents and about 8 percent of those resulting in fatal or hospital-level injuries. Over half of those with injuries involved TMAs. However, 5 of the 10 hospital-level injuries were reportedly minor in nature. Two of the accidents with potentially serious injuries involved vehicles that are outside the design parameters for TMAs. Thus, it appears that only 3 of these 86 accidents involving potentially serious injuries occurred under impact conditions for which these devices were designed. These devices are typically deployed to protect vehicles from encountering potentially severe hazards—portable concrete barrier ends, large shadow vehicles, and work spaces occupied by workers and equipment. It is reasonable to expect that many of these accidents would have resulted in potentially very serious injuries had the vehicles not impacted these safety features first. Thus, it may be concluded that, although impacts on these

TABLE 7 Summary of All Work Zone Accidents: 1994–1996

Feature/Accident Type	Severity		
	Fatal	Hospital	Total
Channelizing Devices	0	4	32
Signs and Related Features	1	2	22
Arrow Panels	1	3	19
Impact Attenuators, Arrestor Nets	0	10	86
Portable Concrete Barrier	6	16	63
Pavement/Construction Features-Vehicle Accidents	0	12	50
Pavement/Construction Features-Pedestrian Accidents	0	3	15
Construction Vehicles	0	28	99
Construction Equipment	3	16	65
Pedestrian Workers/Flaggers	5	21	45
All Construction Features*	16	115	495
All Work Zone Accidents	31	324	1,505

* These totals are slightly overestimated, because a few of these accidents involved more than one feature. Those accidents thus appear in two categories.

devices involved some serious injuries, they undoubtedly prevented a larger number of potentially very serious injuries.

PCBs were involved in fewer reported accidents than TCDs and attenuators—only about 4 percent of all work zone accidents and about 6 percent of those involving fatal or hospital injury. Accidents involving PCBs resulted in more serious injuries than traffic control devices and attenuators combined, although less than half as many total accidents. More than three-quarters of the PCB accidents resulting in serious injury involved secondary impacts before or after the barrier was struck. However, in all six fatal accidents, the PCB was the first significant impact. Very few problems resulted from vehicle rollovers after PCB impact, or from vehicles striking sloped PCB end terminals. In about one-third of the PCB impacts with serious injury, impacts with other vehicles occurred first, and the injury cannot be attributed to the PCB. In about an additional one-third, a secondary impact with other vehicles or devices followed the PCB impact, with severe results in some cases. It is apparent that redirection from PCB impacts has a high severity potential.

Based on damage evidence, it can reasonably be assumed that numerous minor PCB impacts go unreported because they do not involve injuries or other vehicles. Because barriers are deployed to protect vehicles from roadside hazards in work zones and to protect workers from vehicles, it is also reasonable to expect that many of these accidents would have had potentially serious outcomes if the PCBs were not present. Only one PCB penetration was noted, and it did not result in a work space intrusion. These accident figures thus indicate that PCBs generally perform well in reducing harm from work zone accidents. However, because some impacts do result in serious injuries, it is important that PCBs are installed only where needed to protect work zone hazards. It is also essential that PCB design minimizes the risk of secondary impacts, especially cross-median incidents. Although it cannot be overlooked that three of the six PCB fatalities involved motorcycles, it must be recognized that any run-off-road incident involving motorcycles is a potentially serious accident. Ensuring the safety of motorcyclists in such events is well beyond current design parameters.

Pavement surface features, materials, debris, and excavations were involved in about 4 percent of work zone accidents, and about the same percentage of fatal and hospital injuries. Obviously, construction material and excavations adjacent to travel lanes are a potential hazard and need to be protected or delineated to the greatest extent possible. Although pavement surface features themselves rarely resulted in serious harm, a number of injuries occurred in accidents involving secondary impacts or avoidance maneuvers associated with a pavement feature. Very few accidents involved uneven longitudinal joints or pavement edge drop-offs, and it appears that efforts to minimize potential hazards associated with these features are successful.

Nearly 14 percent of all work zone accidents involved contractors' vehicles, equipment, and pedestrian workers (including flaggers), with these accidents comprising over 20 percent of all fatal-hospital injury accidents. Nearly half of work zone accidents directly involved construction features and operations, and over half of those with fatal or hospital injuries involved work vehicles, equipment, and workers. With respect to significant harmful events, these collisions exceed accidents involving traffic control devices, safety features, and other pavement and construction features.

A major concern for work zone safety is so-called intrusion accidents, in which a vehicle enters a defined work space or other areas occupied by construction operations, resulting in injury to a worker, either on foot or in a vehicle or equipment. Considering injuries only to these workers, intrusion accidents are the biggest concern, resulting in nearly two-thirds of serious worker injuries from traffic accidents. Intrusion-type accidents also represent a risk for the traveling public. Overall, half of all fatal and hospital injuries directly involving construction features and operations resulted from intrusion accidents. Although these figures confirm the risk associated with intrusion accidents, it is also observed that many serious accidents occurred when work vehicles, equipment, or workers were in open travel lanes. In fact, more workers were killed in or adjacent to open lanes than in defined work spaces. In addition, 24 accidents involving serious injuries to the public involved work vehicles or equipment in open travel lanes, or about 18 percent of all serious injuries in work zone traffic accidents. The intrusion accidents point out the need for well-designed and maintained traffic control setups to clearly define traffic and work spaces. However, it is clearly also essential that workers are trained to work safely near moving traffic, without subjecting themselves to added risk by entering travel lanes or unprotected areas without adequate precautions. Pedestrian workers, drivers, and operators must adhere to safety rules when entering, exiting, crossing, or traveling in open travel lanes.

CONCLUSIONS

The following conclusions are based on accidents reported on NYSDOT construction projects over a 3-year period, following New York State construction practices and procedures.

- Other than secondary and avoidance collisions, accidents involving channelizing devices rarely resulted in injury to the traveling public or to workers.
- Construction signs and similar devices performed well in most accidents. Two instances of windshield penetration were noted, both resulting in hospital injury. The only fatality involving a sign was not attributable to the sign itself.
- Although all of the TCDs examined appear to perform well by themselves, devices out of position may produce undesirable consequences through secondary and avoidance collisions, windshield penetration, or other undesirable outcomes.
- Although one fatality and three hospital-level accidents involved arrow panels, those injuries are attributable to extremely high impact speeds or other extenuating circumstances. Most accidents involving arrow panels resulted in no injuries.
- Impact attenuators, including TMAs and arrester nets, were involved in a number of accidents and, in most cases, successfully prevented serious injuries. Of the relatively few injuries reported, most could be attributed to impacts by motorcycles or large vehicles, or to improper installation or use of the device. Because of the manner in which these devices are used, many of these accidents would have resulted in more serious injuries had the device not been present.
- PCBs performed well in preventing vehicles from entering hazardous areas. Although a number of serious and fatal injuries were recorded, motorcycle accidents and collisions with other vehicles before striking the PCB accounted for half of them.
- Secondary collisions after PCB impact, including cross-median events, emphasize the importance of designing PCB installations to minimize the risk of secondary impacts.
- Some accidents involving only PCBs resulted in significant injuries, emphasizing the importance of installing PCBs only where needed to protect hazards.

- Accidents involving sloped PCB ends, and accidents resulting in vehicle rollovers, were infrequent and rarely resulted in serious harm.
- Although pavement surface features, excavations, and construction materials were involved in a number of accidents, most of the serious harm resulted from secondary or avoidance collisions.
- Other than pedestrian workers, pedestrian accidents involving construction features or operations, including vehicles and equipment, were rare. Most involved pedestrians tripping and falling.
- Accidents involving construction vehicles, equipment, and workers were frequent, accounting for nearly 14 percent of all work zone traffic accidents.
- Work space intrusions are a serious concern both for workers and for the traveling public. However, work vehicles, equipment, and workers in open travel lanes also accounted for a significant number of accidents and injuries.
- Work zone traffic controls must be designed to adequately separate travel and work spaces. Workers must be aware of the risks associated with moving traffic and must stay out of travel lanes except when proper protection is provided.

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Publication of this paper sponsored by Committee on Traffic Safety in Maintenance and Construction Operations.