Fleet Safety

for Safety Professionals and Fleet Managers

Joel M. Haight Ph.D., P.E.
Editor

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Chapter 4

Vehicle Engineering and Ergonomics

Dennis R. Andrews

LEARNING OBJECTIVES

- Be able to describe the dynamics of the fleet vehicle.
- Mathematically determine the safe operations of fleet vehicles.
- Identify safe human factors for fleet operations in different environments.
- Learn defensive driving maneuvers and methods.
- Recognize the safety implications presented by a workspace environment.
- Identify safety criteria for fleet operators and drivers.
- Understand occupant protection and the biomechanics that can cause injuries.
- Learn about safe operations during the material-handling process in fleet operations.

This chapter contains information relating to the commercial (trucks and buses) motor-vehicle fleet industry and loading and unloading facilities. The information included, while not all-inclusive, was obtained from the industry literature, articles, and the author's experience. The chapter has four major sections: Vehicle Engineering and Tests, Traffic Safety Principles, Vehicle Defensive Driving Tactics, and Ergonomic Issues.

The objective of this chapter is to supply information about and data for the fleet industry as researched by the author. Readers will gain useful new and supplementary knowledge of the fleet industry. The reference section and recommended reading section contain books and articles of interest to motor fleet operators and safety personnel concerning both fleet vehicles and fleet facilities.

The chapter includes information and data on roadway incidents (vehicle accidents), safety, and information for safety programs that will be of interest to fleet owners, fleet safety managers, fleet operations managers, fleet insurance managers, depot operations managers, and anyone else with an interest in motor-vehicle fleet operations and safety.

Vehicle Engineering and Tests

Vehicle Offtracking and Swept-Path Width

Special skills are required to operate commercial and fleet vehicles safely. Large vehicles such as multiaxle trucks and buses operate much differently from passenger vehicles, and their drivers must have special training and maintain concentration while driving to avoid accidents and injury. For example, drivers must learn how to turn and back up articulated vehicles because they require additional space for these maneuvers. Drivers must also be aware of *offtracking*, a term used to describe the difference between the radius of the path of the center of the steering axle and the center of the rear axle for box-type trucks. For articulated vehicles such as tractors and trailers, the spacing along the longitudinal axles of the hitch point must be considered during low-speed turns because the rear wheels do not follow the same path as the front wheels.

The *swept-path width* is the difference between the lateral distance of the inside rear wheels and outside front wheels during a turning maneuver for both box-type and articulated vehicles. The radius of the turn determines the offtracking and swept-path width. The offtracking amount is always less than the swept-path width since offtracking is a measurement from the center of the front and rear axles and the swept-path width is a measurement of the distance between the outside front wheel and the inside rear wheel during a turning maneuver. Buses and similar large vehicles have comparable maneuvering movements but smaller space requirements than do articulated vehicles such as tractors and trailers. Formulas are used to calculate the swept-path width and offtracking of large articulated vehicles and box-type trucks or buses. These formulas supply the necessary data for roadway design. They are particularly important for designing off-ramps for interstate highways and turnpikes as well as for training vehicle operators on proper turning maneuvers (see Figures 1 and 2 for more details).

The formula for low-speed offtracking of a standard two-axle, box-type truck with dual rear wheels is

$$\text{OT (in feet)} = r_1 - r_2 \tag{1}$$

where

r_1 = the turning radius of the front axle
r_2 = the turning radius of the rear axle

To determine the rear-axle turning radius use the following formula:

$$r_2 = \sqrt{(r_1^2 - l^2)} \tag{2}$$

where

l = the wheelbase of the vehicle (the distance between the front and rear axles).

Consider a box-truck vehicle with a front-axle turning radius of 50 feet and a wheelbase of 10 feet (l), the radius of the rear axle is 49 feet (r_2). The calculated offtrack distance is equal to 1 foot (50 – 49). If the wheels of the rear axle are wider than those of the front axle, an adjustment must be made by dividing the difference in the width of the axles by two and adding that number to the result above. For example, if the outside width of the rear wheels is 8 feet and the outside width of the front wheels is 6 feet, the adjustment is 1 (8 – 6 = 2 ÷ 2 = 1). Adding this result to the 1 foot of calculated offtracking distance noted above, the offtracking amount is 2 feet. (Fricke 1990, 78-15–78-16). Since offtracking represents the difference in radius between the centers of both axles, the swept-path width is calculated by adding one-half of the width of each axle to the offtracking result.

A more complicated approach is necessary when dealing with the offtracking of large articulated tractor-trailers and similar vehicles. The formula for a tractor-trailer with ten wheels (3 axles) is

$$\text{OT} = r_1 - r_3 = r_1 - \sqrt{(r_1^2 + l_{ko}^{\,2} - l^2 - l_2^2)} \tag{3}$$

where

r_1 = the radius of the center of the front or steering axle

r_3 = the radius of the center of the rear axle

l_{ko} = the distance of the fifth wheel (also known as the kingpin, the point at which the trailer and tractor are connected) on the tractor to the center of the drive wheels of the tractor,

l = the wheelbase of the tractor

l_2 = the wheelbase from the tractor drive wheels to the rear trailer wheels

If the front-axle turning radius is 41 feet, the tractor wheelbase is 12 feet, the trailer wheelbase is 36 feet, and the fifth-wheel offset is 1.2 feet, the offtrack distance would be approximately 25.4 feet (Fricke 1990, 78-18–78-19). As with the box-truck example, the swept path can be calculated by adding one-half the width of both the front and rear axles to the offtrack distance. If the vehicle comprises a tractor and two trailers, also known as *doubles*, additional data are needed: the rearward overhang of the *pintel hitch* (the hitch between the first and second trailer) location, the length of the *dolly drawbar* (the attachment bar between the first and second trailer), and the wheelbase of the full trailer.

Low-speed offtracking occurs when a combination vehicle makes a low-speed turn—for example a 90-degree turn at an intersection—and the wheels of the rearmost trailer axle follow a path several feet inside the path of the tractor steering axle. Figure 1 illustrates low-speed

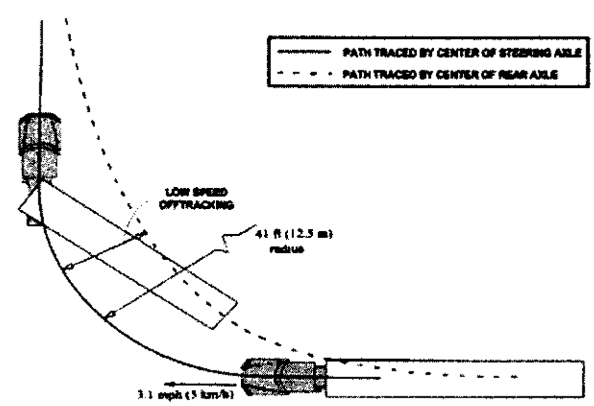


FIGURE 1. Low-Speed Offtracking
(*Source:* FHA 2007)

offtracking in a 90-degree turn for a tractor-semitrailer. Excessive low-speed offtracking makes it necessary for the driver to swing wide into adjacent lanes when making a turn to avoid climbing inside curbs, striking curbside fixed objects or other vehicles. On an exit ramp, excessive offtracking can result in the truck tracking inward onto the shoulder or up over inside curbs. For single trailer combinations, this performance attribute is affected primarily by the distance of the tractor kingpin to the center of the trailer rear axle or axle group. *Kingpin setting* refers to the truck-tractor fifth wheel connection point for the kingpin, which is located to the front of the semitrailer. For multitrailer combinations the effective wheelbase(s) of all the trailers in the combination, along with the tracking characteristics of the converter dollies, dictate low-speed offtracking. In general, longer wheelbases worsen low-speed offtracking.

High-speed offtracking results from the tendency of the rear of the truck to move outward due to the lateral acceleration of the vehicle as it makes a turn at higher speeds. Figure 2 illustrates high-speed offtracking for a standard tractor-semitrailer. The speed-dependent component of offtracking is primarily a function of the spacing between truck axles, the speed of the truck, and the radius of the turn; it is also dependent on the loads carried by the truck axles and the truck suspension characteristics (Fricke 1990).

An Analytical Approach

The Western Uniformity Scenario Analysis (DOT 2004) examines the impact that scenario truck configurations would have on freeway interchanges, at-grade intersections, mainline curves, and lane widths of the current roadway system. It determines what improvements would be needed to accommodate the new trucks, and estimates the costs of these improvements. The focus of this research is to compare the new truck configurations with the current tractor-semitrailers and LCVs operating in the scenario states.

Unlike the analysis for the *Comprehensive Truck Size and Weight (CTS&D) Study*, the base case-vehicle in this analysis varies by state, depending on that state's grandfather laws under the 1991 ISTEA freeze (DOT 2000). The chosen base case-vehicle represents the worst vehicle from an offtracking perspective currently allowed on the analyzed roadway segment. For example, if the worst offtracking vehicle currently allowed on the roadway is a Turnpike Double (TPD), then the TPD is used as the base case-vehicle for that road segment; if the Rocky Mountain Double (RMD) is the worst offtracking vehicle, then it is used as the base case-vehicle; and if the 53-foot tractor semitrailer has the worst offtracking, it is the base case-vehicle. Table 1 shows the base case RMD and TPD for each state. This precise framing of the base case-vehicle is an improvement to the *CTS&W Study*'s analysis that used the 48-foot tractor semitrailer at 80,000 pounds as the base case-vehicle for all roads (FMCSA 2000).

Table 2 shows the low-speed offtracking and swept path for the analyzed configurations. The measure is shown for a standard 90-degree, right-hand turn with a 42-foot radius, negotiated at a speed of 5 kilometers per hour. (Note that the *CTS&W Study* analyzed a 38-foot path radius.) Low-speed offtracking is the one measure where the STAA Double outperforms all the other configurations. The long TPD with twin 48-foot trailers performs the worst of the vehicles.

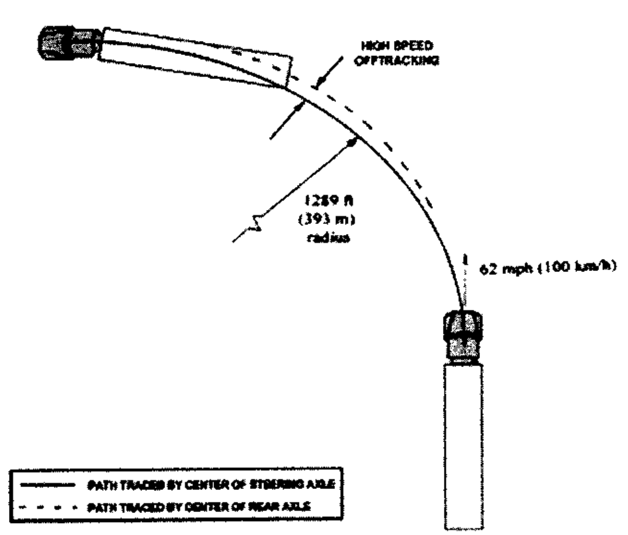


FIGURE 2. High-Speed Offtracking
(*Source:* FHA 2007)

TABLE 1

Base Case-Vehicles for the Scenario States

State	Rocky Mountain Double	Turnpike Double
Colorado	43.5 + 31	48 + 48
Idaho	35 + 20	35 + 20
Kansas	48 + 28.5	45 + 45
Montana	38 + 28	45 + 45
Nebraska	38 + 20	38 + 20
Nevada	48 + 28.5	48 + 48
North Dakota	48 + 28.5	48 + 48
Oklahoma	48 + 28.5	48 + 48
Oregon	35 + 20	N/A
South Dakota	48 + 28.5	48 + 48
Utah	48 + 28.5	48 + 48
Washington	35 + 20	N/A
Wyoming	38 + 27	N/A

(DOT 2000)

TABLE 2

Low-Speed Offtracking and Swept Path of Vehicles

Vehicle Description*	Configuration**	Performance Data (ft) Low-Speed Offtracking	Swept Path
Single (53')	3-S2	16.12	24.12
STAA Double (2@28')	2-S1-2	13.52	21.52
RMD (38', 27')	3-S2-3	18.57	26.57
RMD (38', 27')	3-S2-4	22.08	30.08
RMD (38', 27')	3-S2-2	21.54	29.54
RMD (35', 20')	3-S2-2	15.78	23.78
RMD (38', 28')	3-S2-4	20.06	28.06
RMD (38', 20')	3-S3-2	18.42	26.42
RMD (38', 27')	3-S2-4	21.02	29.02
RMD (43.5', 31')	3-S2-4	20.78	28.78
RMD (38', 27')	3-S3-4	19.13	27.13
RMD (48', 28.5')	3-S2-3	21.87	29.87
Short TPD (2@45')	3-S2-4	27.98	35.98
Long TPD (2@48')	3-S2-4	30.63	38.63
Triple A-Train (3@28")	2-S1-2-2	20.38	28.38
Triple C-Train (3@28")	2-S1-2-2	20.38	28.38

*Vehicle description shows the vehicle type where RMD is a Rocky Mountain Double and TPD is a Turnpike Double. The numbers in parenthesis give the length of each trailer.

**The first number in the series indicates the number of axles on the power unit, the next set refers to the number of axles supporting the trailing unit ("s" iindicates it is a semitrailer), and the subsequent numbers indicate the number of axles associated with the remaining trailing unit.

(DOT 2000)

Vehicle Power Requirements

Large vehicles, whether articulated or not, need sufficient power to operate safely on highways and streets so they can maintain a safe highway speed and pass safely. *Power* is the time rate of doing work, and the *maximum power* an engine can provide is a measure of its performance capability. The power generated by large vehicles can be determined from the formula (ITE 1990, 60–63):

$$P = RV \div 3600 \qquad (4)$$

where

P = the power used in kilowatts (1 kW = 1.341 horsepower; 1 hp = 550 foot-pounds per second)

R = the total resistance to motion of the truck and trailer

V = the speed of the vehicle in ft/s

3600 = a constant representing the seconds in 1 hr

Newton's laws of physics relating to force, mass, and acceleration scientifically demonstrate the need for additional power to haul heavy loads safely. *Force* is the product of mass and acceleration, and it is necessary to overcome inertia, air resistance, tire and roadway resistance, potential energy loss due to the grade or incline of a roadway, and any other conditions that require acceleration power. More force is needed to pull an 80,000-pound trailer than to pull a 20,000-pound trailer, especially along very steep, hilly streets in cities such as San Francisco, Seattle, and Pittsburgh. The average passenger vehicle requires less force to accelerate than a heavier vehicle on the same roadway.

The mass-to-power ratio is helpful in determining and comparing levels of performance. The ratio can be in watts and kilograms or horsepower and foot-pounds. This ratio is important in determining minimum requirements of a selected power plant for a vehicle with known load-carrying capabilities. When calculating this type of power ratio, consideration should be given to the power source—diesel or gasoline. Diesel engines produce more thrust than gasoline engines since diesel fuel is ignited by compression. For both maintenance and durability, the overwhelming choice for a commercial vehicle power source is a diesel engine rather than a gasoline engine. Diesel engines are much more expensive than gasoline engines due to their heavier construction. Power-requirement considerations should include vehicle operating ranges, locations, and conditions. Driving in a more mountainous terrain requires more horsepower than driving in a typical inner city unless the city has very steep and hilly streets.

The mass-to-power ratio is the measure of a vehicle's ability to accelerate and maintain speed up grades. Mass can be thought of as an indicator of resistance to motion—the higher the mass-to-power ratio, the less the acceleration performance, and the lower the mass-to-power ratio, the greater the acceleration performance. A typical passenger vehicle's mass-to-power ratio is 1550 kg (3425 lbs) to 140 kW (188 hp) of power. A tractor semitrailer's is approximately 11,000 kg (24,310 lbs) to 240 kW (322 hp) of power (ITE 1990, 57–60). A typical passenger car has approximately 50 percent of the manufacturer's rated engine power available to travel 100 kilometers per hour (approximately 61 miles per hour); a large truck has approximately 94 percent of the manufacturer's rated engine power available. These estimates are useful in determining maximum acceleration rates and maximum speeds on grades for engine power in relation to engine speed and values of acceleration (ITE 1990, 50–54).

Acceleration is determined by the change in velocity over a period of time and is expressed as feet per second per second, or fps2. Since large vehicles have more mass than average passenger cars, large vehicles accelerate more slowly than passenger cars. As a general rule, the range of acceleration for large, loaded trucks is from 0.3 to 1.6 fps2 (see Figure 3).

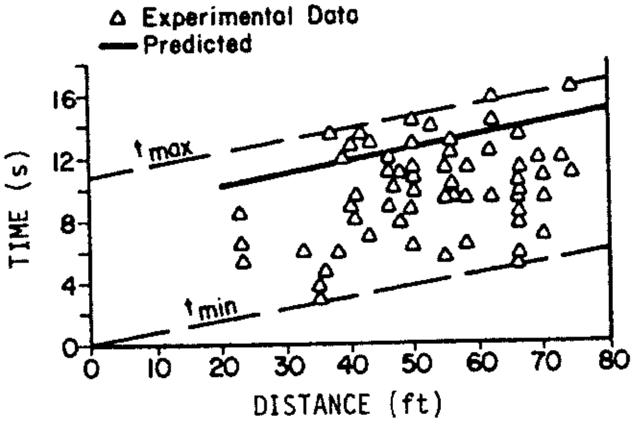


FIGURE 3. Field observations of times for 19.8-m (65-ft) tractor-trailer trucks to clear intersection distances after starting from a stop
(*Source:* Transportation Research Board (TRB) 1997)

Transit Buses

Primary human-factors considerations for public transit buses include the following (Woodson 1992, 85):

1. ***Driver:*** Clear visibility in all directions (360 degrees), ability to visually monitor passengers, lack of interior reflection at night, and a comfortable seat for lengthy occupancy. Figure 4 is a recommended layout for a transit bus-driver station. (Woodson 1992, 296).
2. ***Onboard passengers:*** Level floor with wide aisles, handrails that are easy to grasp, comfortable seating with sufficient room for knees and elbows, good visibility for seeing stops, air conditioning, minimum noise, and a reasonably comfortable ride.
3. ***Boarding passengers:*** Ability to identify oncoming buses from a distance and convenient entry handrails.
4. ***Service personnel:*** Convenient access to all maintenance components, especially those requiring frequent service.

The entry threshold for passengers must be low enough so that passengers do not have to stretch to step onto the first step from the ground or curb. It is recommended that a ramp sufficient to accommodate wheelchairs be considered for the main entrance. Aisles should be level; a grade could create a hazard for walking or standing passengers. Passenger seats are not usually fancy on intracity buses, but comfortable seats are required for buses traveling long distances. Seating on long-distance buses should be roomy so passengers don't find it necessary to stand or walk in the aisle. Arm rests should be cushioned and ergonomically designed, and reading lamps and footrests should be provided.

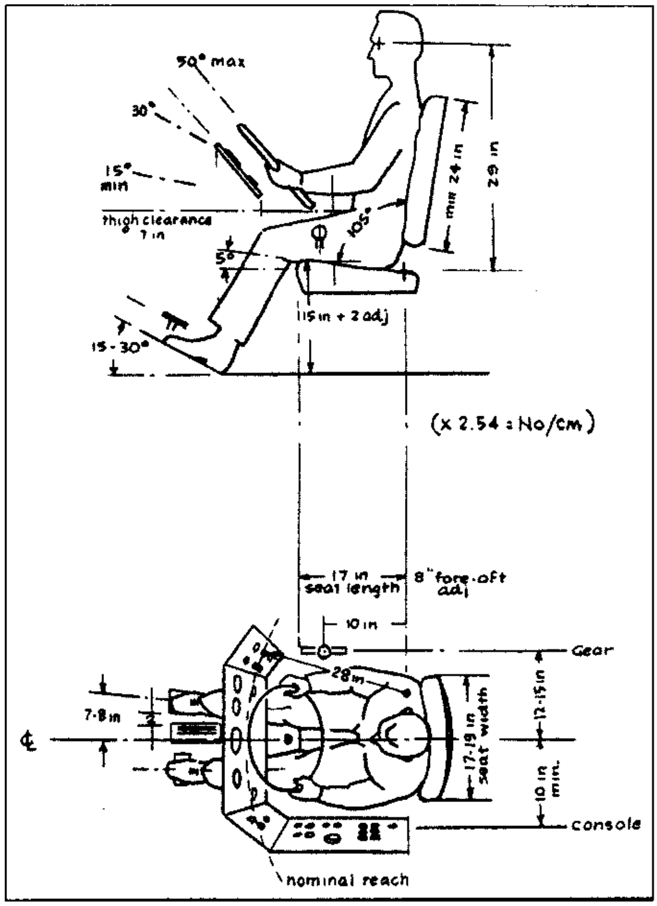


FIGURE 4. Guidelines for bus-driver-station layout
(*Source:* Woodson 1992, p. 296)

The primary consideration in designing intercity buses is the comfort of passengers taking long rides (Woodson 1992, 86). Intercity bus-seat dimensions can be approximately the same as those for city buses, but intercity bus seats must have headrests and reclining backs. A seat that reclines 30 degrees allows a passenger to lean back far enough to prevent his or her head from falling forward. If a seat is able to recline to 45 degrees, it should be adjusted to a horizontal position, which is more comfortable when passengers stretch their legs. The minimum clearance between the seat back in front of a passenger and the forward portion of the passenger's seat is approximately eight inches.

Transit bus companies and those who have the responsibility of locating and posting bus-stop signs must consider and document many issues:

- the safety of passengers entering and exiting the bus
- the impact on parking and adjoining landowners' traffic patterns if the stop is to be located in a business area

- the positioning of stops near intersections (whether to place the stop on the far side or near side of an intersection or midblock) (It is unsafe for a bus to stop at a stop sign, cross through the intersection, and then stop a second time at a bus stop on the opposite corner.)
- crosswalk safety (Onboard signs should direct passengers to wait until the bus departs before crossing streets, and not to cross in front of the bus. At controlled intersections, stops should be placed at a sufficient distance from crosswalks so that pedestrians are not tempted to enter the roadway from behind a stopped bus.)
- the positioning of bus stops with regard to parking areas (They should not be placed within parking areas since normal traffic may have a tendency to park near or within the bus-stop location and create a safety hazard for passengers exiting the bus) (NJ Transit Corp 1998).
- distance from other bus stops
- signage (Bus-stop signs should not be so large that they block regulatory signs or impair the view of the bus driver or other drivers. Usually local townships have regulations about bus-stop-sign locations, and unless there are strong safety objections, signs should be placed accordingly) (Woodson 1992, 87).

All transit companies should have their own procedures and policies regarding the safety of their riders as well as methods of determining bus-stop locations with the safety of both the riding public and driving public in mind. A valuable source of information about bus-stop placement is "TCRP Report 19: Guidelines for the Location and Design of Bus Stops" (TCRP 1996). Companies must review and revise policies and procedures as circumstances change. A written policy is an excellent tool for training employees.

Braking Performance

The efficiency of braking by a vehicle is considered its *braking performance.* How well braking systems perform depends on maintenance, design, and environment. Braking performance (Ma_x) is determined by vehicle weight, linear deceleration, the braking force of the front and rear axles, aerodynamic factors, and the rate of linear elevation of the roadway. The formula for braking performance is (Gillespie 1992, 21–42):

$$Ma_x = -W/g\,D_x = -F_{xf} - F_{xr} - DA - W \sin \theta \qquad (5)$$

where

W = the vehicle weight
g = the gravitational acceleration
D_x = the rate of deceleration in feet per second
F_{xf} = the front-axle braking force
F_{xr} = the rear-axle braking force
DA = the aerodynamic drag
q = the uphill or downhill grade

The gravitational acceleration (g) is constant at 32.2 fps^2. The braking force can be determined through indices (tables) or from testing. Aerodynamic drag, which can be found in wind tunnel tables, varies among vehicles depending upon their configuration (e.g., a Corvette automobile has a lower air drag than a flat-front truck tractor). The angle of rise or fall of a hill can be determined by measurement or by estimating. Most vehicles are equipped with antilock brake systems. Constant pressure during deceleration (rather than pumping the brake pedal) will increase the performance of antilock brakes, allowing the driver to maintain control of the vehicle.

A test bus experienced frontal impact three times with three different speeds (see Tables 3 and 4). The vehicle's dimensions were:

- length: 11,000 mm
- width: 2500 mm
- height: 2940 mm
- axle distance: 5570 mm
- front/rear overhang: 2630/2800 mm

TABLE 3

Frontal Impact on the Test Bus

Measured Values	Bus Frontal Impact onto Rigid Wall 3,6 km/h speed 6,98 km/h speed 29,76 km/h speed		
Maximum impact force at the left longitudinal beam (k/N)	180	220	780
Maximum impact force at the right longitudinal beam (k/N)	160	190	390
Resultant impact force (k/N)	320	390	1100
Maximum acceleration on the floor above the CGV (g)	3	4	12
Maximum resultant acceleration in the Hybrid II head (g)	3	10	60
Measured maximum femur force in the Hybrid II dummy (kN)	1,1	1,3	1,6

(*Source:* FMCSA 2003)

TABLE 4

Buses Involved in Fatal Cashes by Operator Type, 1999–2005

Carrier Type	Number	Percent
School	857	3.18
Transit	731	32.5
Intercity	83	3.7
Charter/Tour	256	11.4
Other:		
Private company	20	0.9
Nonprofit Organization	62	2.8
Government	33	1.5
Personal	3	0.1
Contractor for school district	40	1.8
Other	93	4.1
Other subtotal	*251*	*11.1*
Unknown operator type	74	3.3
Total	**2252**	**100.0**

(*Source:* FMCSA 2003)

As one can see from Figure 5, in a frontal impact the right and left sides of the bus do not have the same force. Also the floor deceleration peaks at about 15 Gs.

Large tractor-trailer combinations have an engine-braking mechanism that uses the engine to retard the forward motion of the vehicle. This is commonly called a "Jake brake" after the company that invented the system—Jacob Manufacturing. The system works by retarding the speed of the vehicle through the use of the engine's exhaust system, which is able to absorb enough energy to stop a 75,000-pound gross combination vehicle without the use of the service brakes at 19 mph on a 10 percent grade (Fitch 1994, 239–254). The system can be adjusted by the vehicle operator.

The two most common types of brake systems are hydraulic and pneumatic. *Hydraulic* systems are used on typical passenger vehicles and use brake fluid to activate the brake shoes or calipers to decelerate the vehicle.

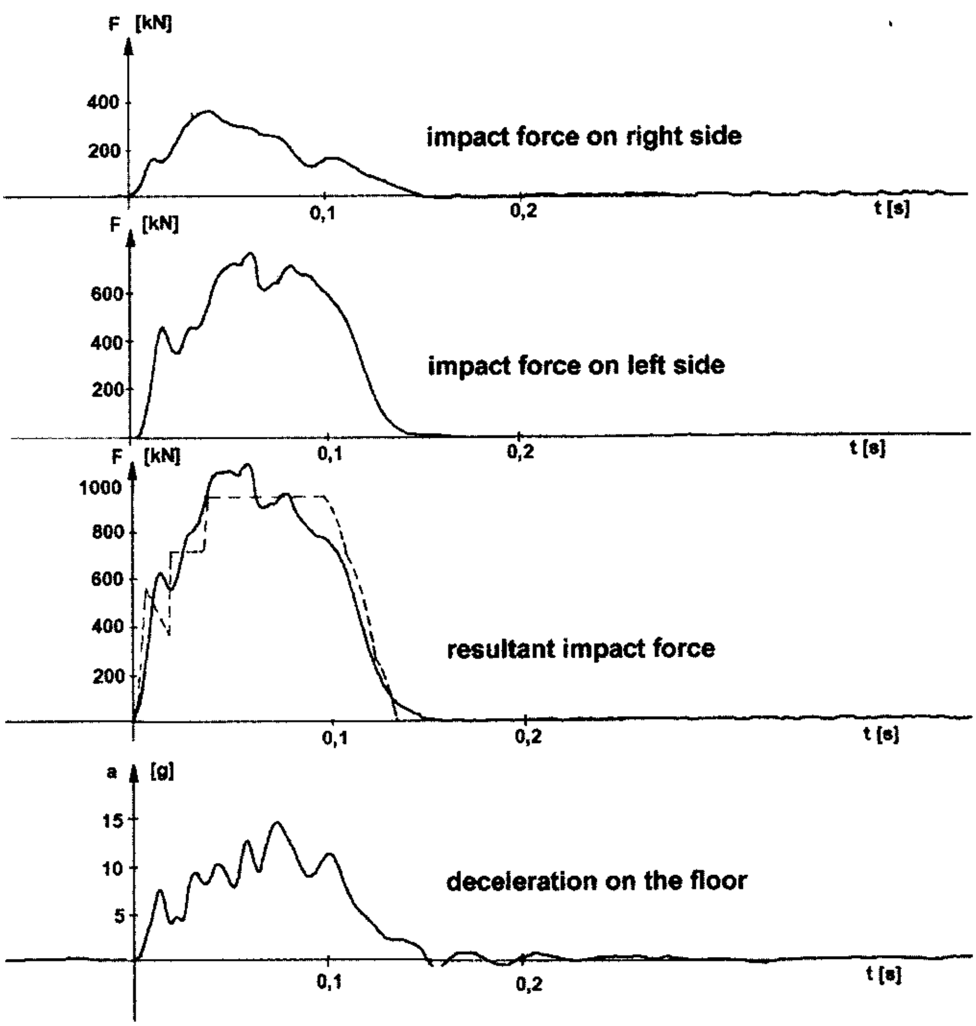


FIGURE 5. Frontal impact of 1K 411 bus; impact speed 29,76 km/h (*Source:* FMCSA 2003)

Typical passenger vehicles have antilock brake systems. Hydraulic brake systems must be checked periodically to ensure that fluid has not leaked or dropped to an unacceptable level due to worn gaskets or hoses. Hydraulic systems must be cleaned (flushed) periodically and new fluid added, since it is very difficult to stop contaminants from entering the system.

Pneumatic brake systems, also known as air brakes, are usually found on large heavy vehicles, such as tractor-trailers (see Figures 6a–d). *Brake lag* is a term used to describe the time it takes for a pneumatic brake system to reach full pressure and begin to lock or retard the wheels. In passenger vehicles with hydraulic systems, the brake lag is negligible—approximately 0.1 second (100 milliseconds). Some experts estimate the brake-lag time for tractor-trailer combinations at 0.5 to 1.0 second, while others estimate it at 0.25 to 0.5 second depending upon the number of trailers.

Another safety component that influences braking performance on tractor-trailer combinations and other vehicles with pneumatic brake systems is the *slack adjuster*. The term *slack adjustment* refers to the distance needed to adjust the actuation arm to fully compress the brake lining and the brake drum. If the slack adjustment is not properly set, braking performance will be greatly reduced. There are usually slack adjusters for each braking wheel. The specific ranges stated by the manufacturer should be adhered to when adjustment is done. Some pneumatic brakes have automatic adjusters, but those also must be checked for proper adjustment.

Aerodynamics and Tires

The aerodynamics of a vehicle is important for fuel economy and vehicle control. A person traveling down a roadway in a vehicle and with one hand out the window with the narrow part facing forward, will feel little resistance. But if the hand is turned so that the palm is directly forward and into the wind, he will feel greater resistance. This *aerodynamic resistance* decreases vehicle fuel mileage. The geometric design of most vehicles used to carry goods, such as semitrailers, is rectangular. The tractor or cab of a tractor-trailer combination, however, usually has a more aerodynamically efficient shape.

Lift resistance—the downward force on a vehicle due to the motion of air over and around it—varies with the geometric design of the vehicle. Lift resistance can easily be understood by watching a drag race or NASCAR race. Dragsters and NASCAR race vehicles have a wing on the rear to keep them on the road at high speeds. A Corvette has a greater lift-resistance force than an SUV or a tractor-trailer combination since the rear of a Corvette

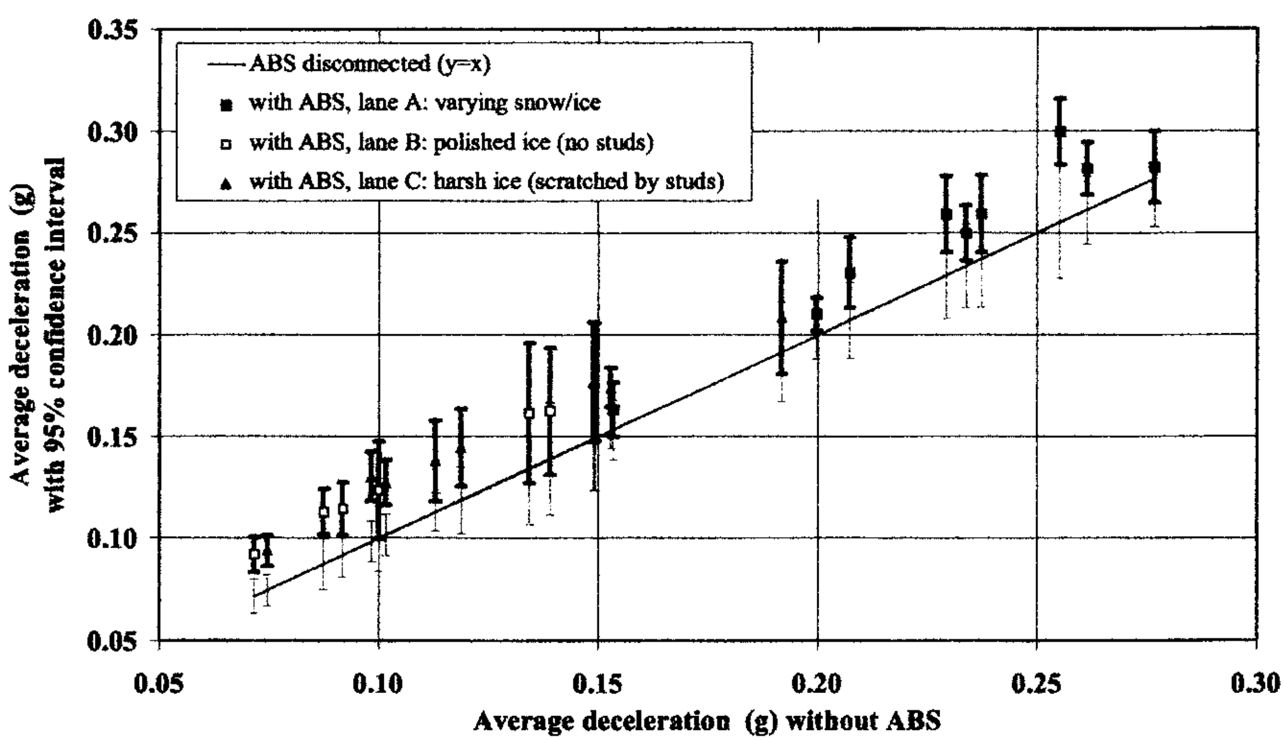


FIGURE 6a. Deceleration capacity on 3 snowy/icy lanes (A, B, C) with ABS in function (y) or disconnected (x). Each value represents one tyre type average over all drivers with 95% confidence interval. Nine tyre types on lanes A and C; 6 unstudded types on lane B (*Source:* Strandberg 1998)

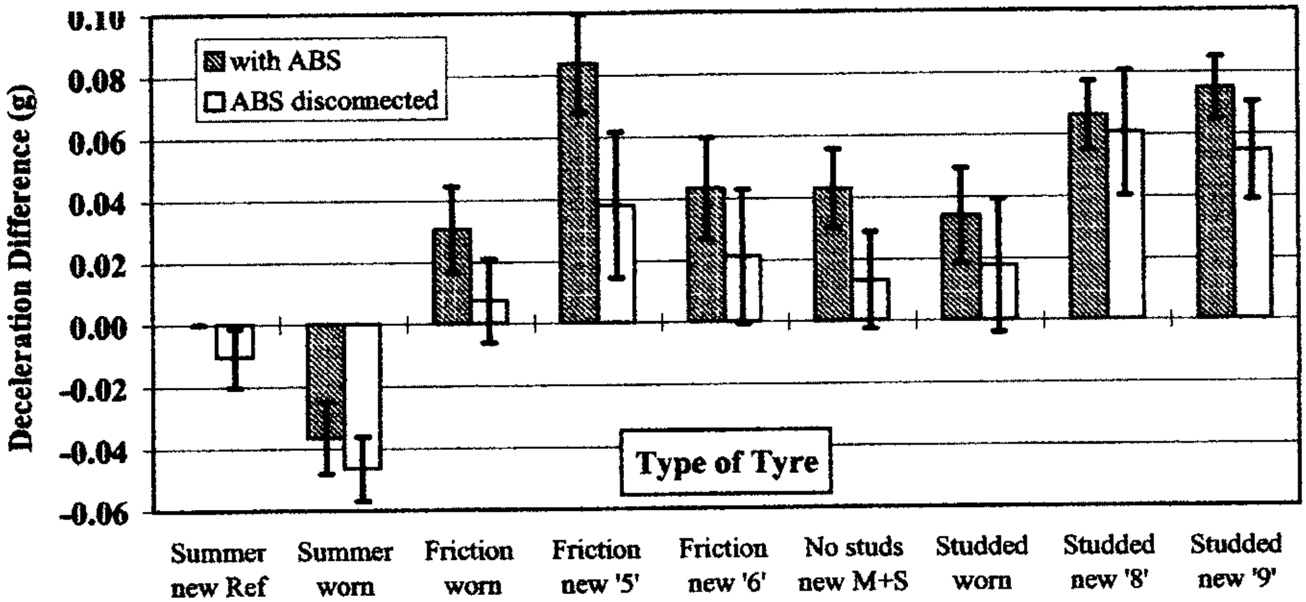


FIGURE 6b. Deceleration difference between certain tyre-ABS configurations and reference summer tyres with ABS. Paired comparisons for each driver on lane A (carrying snow and ice). Average over 24 + 24 + 18 = 66 drivers with 95% confidence interval (*Source:* Strandberg 1998)

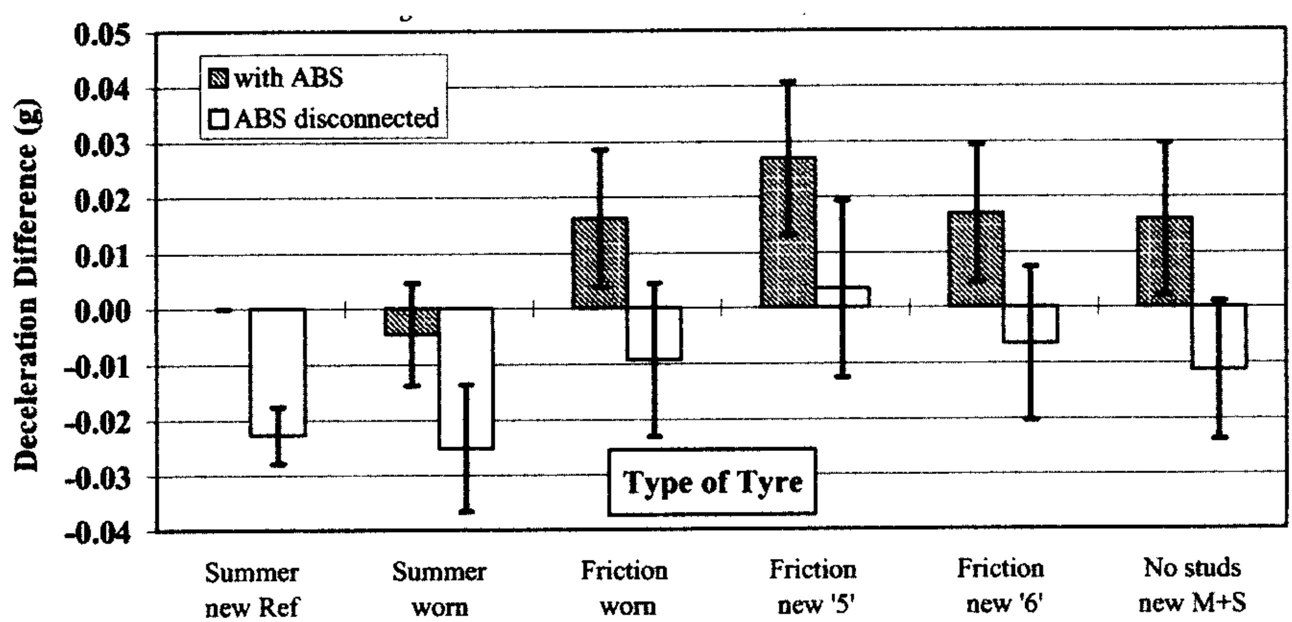
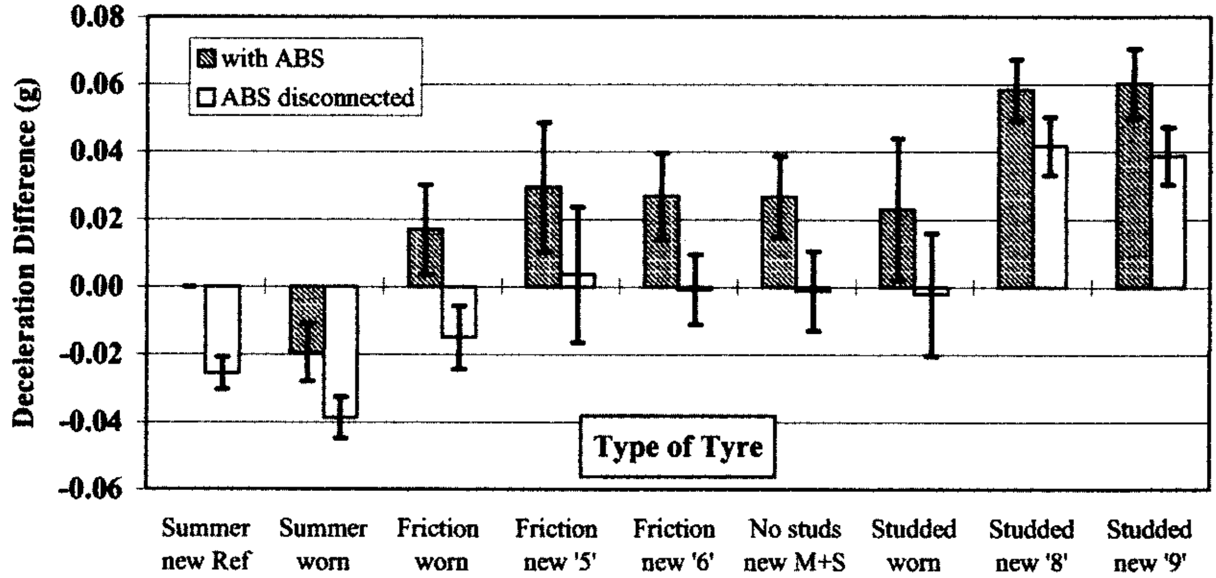


FIGURE 6c. Deceleration differences between certain tyre-ABS configurations and reference summer tyres with ABS. Paired comparisons for each driver on lane B (polished ice surface, no studs allowed). Average over 24 + 24 + 18 = 66 drivers with 95% confidence (*Source:* Strandberg 1998)



NOTES:

a1) New summer tyres—Reference type (same four-wheel individuals as b1 and c1).
a2) New "friction" tyres. Hysteresis rubber for ice and snow adhesion. Asian makes. ID no. 6.
a3) New unstuddedM+S tyres. Made for studding but without studs.
a4) New studded types. 105 studs per type. Same make and type as a3. ID no.8.
b1) New summer types—Reference type (same four-wheel individuals as a1 and c1).
b2) Worn friction tyres. 5 years old. Tread pattern depth 5 mm.
b3) Worn summer tyres. 5 years old. Tread pattern depth 3-5 mm.
b4) New studded tyres. 110 studs per tyre. Same four-wheel individuals as c4. ID no. 9.
c1) New summer tyres—Reference type (same four-wheel individuals as a1 and b1).
c2) New "friction" tyres. Hysteresis rubber for ice and snow adhesion. European. ID no. 5.
c3) Worn studded tyres. 5 years old. Tread pattern depth 5 mm.
c4) New studded tyres. 110 studs per tyre. Same four-wheel individuals as b4. ID no. 9.

FIGURE 6d. Deceleration differences between certain type-ABS configurations and reference summer tyres with ABS. Paired comparisons for each driver on lane C (harsh ice surface scratched by studs). Average over 24 + 24 + 18 = 66 drivers with 95% confidence interval (*Source:* Strandberg 1998)

is designed to create a downward airflow. Aerodynamics also affects possible loss of control from strong crosswinds. Vehicles are aerodynamically efficient for forward movement and are tested in a wind tunnel for centerline forces, but crosswinds are extremely difficult to counteract (Gillespie 1992, 79–103). Vehicles are not efficiently designed for crosswinds and can be very difficult to control when crosswinds are present. This is especially relevant for tractor-trailers.

Tires are extremely important to safe vehicle movement and also affect fuel efficiency. An underinflated tire creates greater rolling resistance and consequently is less fuel efficient. Overinflated tires cause uneven wear; therefore, the most important factor in tire safety, the depth of tread, is decreased, which may not be noticed until an accident occurs.

Besides inflating tires properly, one must align and balance them in order to maintain safe tire wear and fuel efficiency. Tread depth and wear are very important, since the tread disperses water on roadway surfaces and inhibits hydroplaning and loss of control.

Heavy Vehicle Tire Blowout

Tire blowout of mechanical origin involves the condition of the materials (tire, rim) and the quality of the assembly. While less spectacular than an explosion, the energy released during blowout can lead to significant injuries if people are directly in the projection trajectory of the debris. Four events of a mechanical origin that can cause a tire to blow out are (ASTE 2009):

1. *Overpressurization of the tire:* Possible causes include:
   - poorly adjusted compressor pressure
   - pressure-gauge or valve problem
   - incorrect mounting on the rim and
   - voluntary overpressurization when seating the tire on the rim.
2. *Zipper failure:* A design defect, an overloading, or an impact can cause a weakness, a cracking, or a rupture of the tire carcass (see Figure 7). The result can lead to significant air loss, the projection of tire fragments, and a sudden drop in

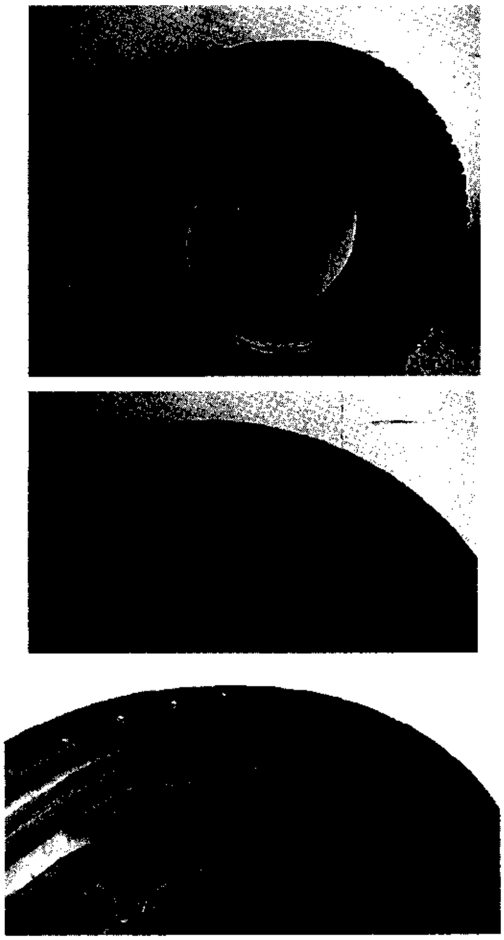


FIGURE 7. Zipper failure in heavy truck tire blowout
(*Source:* ASTE 2009)

pressure at this location, sometimes accompanied by a mark resembling an unstitched or unzipped fabric. Possible causes include:

- deterioration of the envelope exposing the plys or the belts of the tire to contamination by air or humidity
- mechanical impact that damaged the tire's structure
- driving with an underpressurized tire, below 80% of the recommended pressure
- driving with overpressurized tires
- overloading
- loss of mechanical properties due to heat, pyrolysis, or thermo-oxidation
- significant carcass wear
- design defect in the weave of the tire cord

3. *Tire-demounting:* Tire-demounting occurs when the tire accidentally and suddenly comes off the rim with a violent release of air or other gases from inside the tire. Possible causes include:
    - mechanical impact, more or less violent, on the rim or the tire
    - abnormal wear of the rim (edge)
    - deformation of the rim or one of its components following overheating
    - incorrect original mounting of the tire
    - incompatible parts of the rim (multipiece rim)
    - dimensional or other incompatibilities of the rim and tire
4. *Tire in poor condition or with a structural weakness:* A worn tire or even a new one can have a somewhat noticeable structural defect. It may then be unable to withstand normal inflation pressure.

Steady-State Cornering

Steady-state cornering is a term generally used to describe the handling characteristics of a vehicle. It is important to understand the handling of fleet vehicles since these vehicles operate in all types of environmental conditions. A tractor-trailer's cab has steering in the front axle only; the other axles of the tractor follow. In a turn, the inside front wheel has a greater steering angle than the outside front wheel, and the average of the inside and outside front wheel angles is called the *Ackerman angle.* The angle between the heading of the front wheel and the actual travel path of the wheel is known as the *slip angle.* This angle becomes greater—and the tractor becomes more difficult to control—as the friction value between the tire and the roadway surface becomes smaller (Gillespie 1992, 54–59). The *neutral steering angle* is one in which the steering angle is the same as the Ackerman angle. This occurs when the slip angle is the same for both the front and rear tires. *Understeering* occurs when the front wheels slip to a greater extent laterally than the rear wheels, and *oversteering* occurs when the rear wheels slip to a greater extent than the front wheels.

Suspension, or weight shift, plays a crucial part in cornering because the movement and displacement of the cargo can greatly affect the steering of the vehicle. Trucks that carry liquids have a baffle system within the tank so that movement of the liquid during cornering is generally stabilized. Federal transportation guidelines pertaining to cargo stabilization and securing have been established to address the issue of weight shift, as well as the possibility of personal injury during the unloading process. Suspensions are usually a trade-off between stiffness and the ability to absorb rough roadways. Steering geometry includes the understanding of and proper adjustment relating to the toe-in, caster, and camber of the wheels, especially the wheels on the steering axle.

When wheels are adjusted to have *toe-in*, their front edges are closer together than their back edges. *Caster* is a backward tilting of a wheel in relation to the center of the suspension. *Camber* refers to the amount that the tops of the wheels tilt outward (Gillespie 1992, 60).

Rearward Amplification

When a combination vehicle makes a sudden lateral movement, such as to avoid an obstacle in the road, its various units undergo different lateral accelerations. The front axles and the cab exhibit a certain kind of acceleration, but the following trailer(s) have greater accelerations. This has been experimentally verified and quantified. The lateral acceleration of the first trailer may be twice that of the tractor, and the lateral acceleration of a second trailer may be four times as much.

The factors that contribute to increased lateral accelerations of the trailing units is the phenomenon known as *rearward amplification*:

- number of trailing units
- shortness of trailers (longer ones experience less amplification)
- loose dolly connections
- greater loads in rearmost trailers
- increased vehicle speeds

Quantifying rearward amplification in terms of multiples of lateral acceleration is relevant to vehicle design, but is not generally relevant to highway geometric design. The Transportation Research Board (TRB) recommended that a reasonable performance criterion would be that the physical overshoot that a following trailer exhibits during such a maneuver, relative to its final displaced lateral position, be limited to 0.8 m (2.7 ft) (TRB 1997).

Suspension Characteristics

The suspension of a heavy vehicle affects its dynamic responses in three major ways:

1. determining dynamic loads on tires
2. orienting the tires under dynamic loads
3. controlling vehicle body motions with respect to the axles

Suspension characteristics can be categorized by eight basic mechanical properties (TRB 1997):

1. vertical stiffness
2. damping
3. static load equalization
4. dynamic interaxle load transfer
5. height of roll center
6. roll stiffness
7. roll steer coefficient
8. compliance steer coefficient

Rollover

Rollover is a serious problem in commercial trucks that have a high center of gravity. The propensity for rollover greatly increases with the height of the center of mass above the ground. For example, it is widely known and has been demonstrated that SUVs have a high propensity to roll over—approximately five times that of standard passenger vehicles. The problem is exacerbated when quick movements from side to side are performed. Given the size of the typical commercial fleet vehicle, any quick movements can be hazardous and create a catastrophic event. If vehicles are carrying toxic chemicals, the hazard is multiplied many times.

Rollovers can occur if a vehicle attempts to enter a curve at a speed greater than the design speed of the curve. The cross slope or superelevation is usually a positive bank, which helps the vehicle to maintain an upright position in a curve. The radius of the curve and the cross slope are important factors and affect each other depending upon the grade of the road and the speed of the vehicle. Heavy trucks may have a rollover threshold (stability factor) of 0.4 to 0.6; in contrast, a sports car's threshold is 1.2 to 1.7. These values are unitless since they are ratios based on the height of the center of mass and the track width of the vehicles. The formula to determine the stability factor of a vehicle where there is no superelevation or roadway cross slope is

$$SF = t/2h \tag{6}$$

where

SF = the stability factor,

t = track width

h = the height of the center of mass

If there is a cross slope, the formula is

$$SF = (t/2 + \psi h)/h \tag{7}$$

where

ψ = the roadway's cross-slope angle (Gillespie 1992, 309–317)

Vehicles can also roll over if curbs or other low objects trip them (strike them below the center of mass) as they move laterally. These types of rollovers are generally preventable if the driver uses common sense and safe driving techniques.

The following points (McKnight and Bahouth 2009) apply to rollovers:

- Although they account for about a tenth of all large truck crashes, rollovers result from causes that are relatively unique to the vehicle and where it is driven.
- The majority of rollovers occur in curves, primarily on- and off-ramps where misjudgment and being in a hurry lead to speeds that are excessive to the vehicle's high center of gravity.
- Failure to adjust speed to the load and the stability, height, and weight of the load is a cause relatively unique to rollovers.
- Inattention, dozing, and distraction often necessitate sudden course corrections, leading to rollovers. However, they play a smaller role in crashes involving trucks than other vehicles.
- Three control errors that are relatively unique to truck rollovers are turning too sharply, turning too little to remain on the road, and overcorrecting steering errors.
- A quarter of rollovers result from problems over which drivers have no control. Half of those are the fault of other drivers, far less than is the case in other truck crashes.
- Large truck instructional programs could reduce the incidence of rollover by the use of videos to expose truck drivers to situations leading to rollovers and through simulation to help drivers develop avoidance skills without being exposed to danger.

Data on speed- and control-related rollovers are presented in Tables 5 and 6.

TABLE 5

Speed-Related Rollovers

Cause	Number	Description
Speed	108	Speed excessive to circumstances
Curves	77	Curves taken at excessive speed
Misjudgment	67	Misjudged speed at which the curve could be taken
Hurrying	13	In a hurry and disregarded speed limitation
Anger	3	Loss of temper in response to other road users
Oversight	3	Failure to notice speed signs
Loads	26	Not adjusting speed to stability, weight, height
Brakes	15	Not adjusting speed to known poor braking
Road	11	Not adjusting speed to road conditions
Intersect	10	Not adjusting speed to sharp turn at intersection
Vehicles	5	Not adjusting speed to vehicles ahead
Tires	3	Not adjusting speed to worn tread
Sight distance	2	Not adjusting speed to limited sight distance

(*Source:* McKnight and Bahouth 2009)

TABLE 6

Control-Related Rollovers

Cause	Number	Description
Control	46	Errors in controlling motion of the truck
Steering	20	Oversteering or understeering
Overcorrection	19	Overcorrecting after error (off road, out of lane)
Following distance	7	Failing to keep distance from vehicle ahead
Avoidance maneuvers	6	Responding to vehicles/road incorrectly
Downshift	3	Failure to downshift for speed control
Braking	3	Improper braking (e.g., locked brakes)

(*Source:* McKnight and Bahouth 2009)

Emergency Fleet Vehicles

Although emergency fire vehicles are not usually thought of as fleet vehicles, they have evolved in their own manner within the transportation system.

Emergency vehicles such as fire trucks may have specialized equipment such as flashing lights and sirens, may be painted special colors, and may have areas of special reflectivity. Flashing lights were invented to bring attention to persons at a distance that an emergency vehicle was approaching. The flashing intensity, duration, and ability to be detected at a distance are of prime importance. Emergency flashing lights primarily convey the message that drivers must give emergency vehicles the right of way. Since they are used among other lights, drivers must be able to identify them and respond quickly in order to avoid an accident.

Color is a key visual component in any emergency vehicle fleet accident-prevention policy. Red may not be the best choice for emergency vehicles because under normal circumstances people have difficulty seeing red objects. During the day, in fact, red is one of the most difficult colors to see, and at night everyone is practically "red blind." A range of yellow colors—from greenish-yellow to yellowish-green—is most easily detected day and night (Southhall 1961, 273). School-zone and school-crossing signs are now made with lime or yellowish-green backgrounds. Lime is also seen significantly faster than red in the peripheral (off-central) view, which is important because peripheral vision is most often responsible for early detection.

Colors and shapes that contrast with their backgrounds are essential to use in the design of emergency

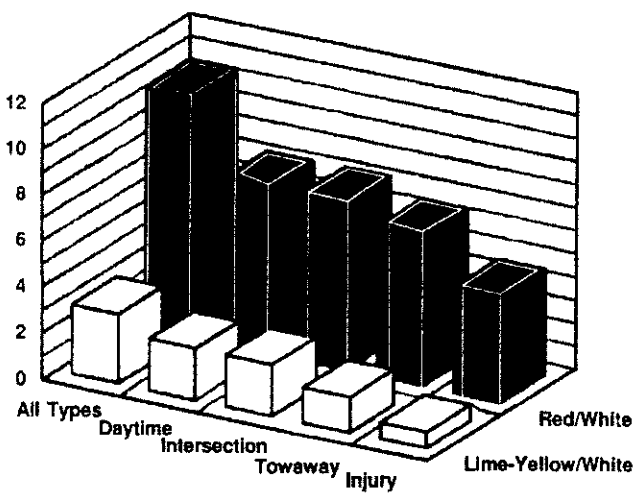


FIGURE 8. Comparison of accident incidents involving fire engines of different colors (*Source:* Solomon 1984)

vehicles. NASA studied this subject and determined that the yellowish-green or greenish-yellow colors, rarely found in nature, attract more attention because they stand out more than other colors. For example, lime-yellow/white fire engines are safer than red/white vehicles. A study by Stephen Solomon published in *Firehouse Magazine* (June 1984) regarding *safety color* reported that red vehicles were involved in twice as many accidents as lime-yellow ones (see Figure 8). To understand this, the article examined the four-part reaction/perception driver-avoidance maneuver.

Use of fluorescent and retroreflective materials for the emergency vehicle fleet is another issue that must be addressed by fleet operators and safety managers.

Fluorescent materials convert the energy from light into different color wavelengths. Fluorescent products are usually brighter and more eye-catching than non-fluorescent products and are used mainly during daylight hours. Fluorescent yellow-green is the most detectable color. Fluorescent signs and warnings are very noticeable when new, but their brightness diminishes over time with exposure to sunlight. Consequently, fluorescent objects must be repainted or have new striping applied. This type of material needs constant maintenance and review to be efficient throughout its lifetime (Southhall 1961, 273). Fluorescent colors do not reflect or radiate light at night.

Retroreflective materials are used for nighttime detection of signs or vehicles. They use microscopic beads, lenses, or prisms embedded in substances or added to paint. Retroreflective materials have the ability to reflect light back to its origin. As light moves away from the center of the axis of the retroreflective material, the brightness or reflectivity diminishes greatly. One of the greatest safety uses for retroreflective materials is on commercial vehicles such as tractor-trailers, where the materials can assist in reducing underride collisions. One of the problems with outlining the side of a trailer with one line of retroreflective materials is that this does not provide adequate information when the trailer is not viewed in profile. If the rear of the trailer is marked with reflective material in a right-angle pattern, vehicles approaching from the rear have more information about the size and shape of the trailer.

Phosphorescent materials glow in the dark. They absorb light energy and radiate that energy after the light source is removed. This absorption and emission of light does not last long enough to be of value on emergency fleet vehicles.

Emergency vehicles can create a highway hazard even after they have stopped moving, so fleet operation managers must be sure that emergency vehicles have high conspicuity when stopped at a vulnerable location, such as on a highway. Proper lighting and use of warning devices must be understood by emergency vehicle operators so that the vehicle itself does not become part of the emergency scene.

Once an emergency vehicle arrives at a scene, operators should deploy all warning devices—signal arrows, signs, cones, and flares—as soon as possible.

Traffic cones have no nighttime value since they are normally unlit, so they should be used in daytime only. Highway flares are often used in close proximity to emergency scenes, but their sparks make them a hazard near flammable fuel spills. The negative characteristics of flares include not only their sparks but the amounts of smoke and red/orange flickering flames they generate. The flickering flames can detract from the overall attention demanded by emergency lighting because they may reduce or negate the effectiveness of other flashing lights. Smoke and flares contribute to a visually cluttered background and can confuse unsuspecting drivers approaching the scene (Southhall 1961, 276).

As a general rule, the longer emergency vehicles and personnel must be at a scene, the greater the possibility of injury to emergency fleet personnel, hence the more durable the traffic warning controls should be.

Creating a Risk Plan

Responding to emergencies such as fires, police calls, and accidents is a dangerous business. The danger is not limited to transportation to the scene but also at the scene and in dealing with victims. The purpose of a risk-management plan is to control the risk as best as possible to minimize the danger. Risk management is not static; it is a fluid process. At the end of the process, continual review and updating is crucial to maintaining an effective and efficient health and safety program.

Losses have an effect on personnel, property, legal liability, and time. The most important of these is the personnel. Because the responders must enter into or about buildings, crashed vehicles, or dangerous scenes, personnel may be, and at times are, lost through injury or death. While fatalities or injuries are always to be avoided if possible, they do happen and, as a consequence, are costly to the emergency organizations and the team. These costs can be controlled through risk-management planning and recovery planning. Property losses include damage to the emergency organization's property, such as vehicles, which are very expensive since they are usually custom-made equipment. The loss includes cost of a replacement for repair. In recent times, legal liability has become a substantial portion of the insurance premium package and also a large part of the planning. It is no longer to be taken for granted that the victim will feel fortunate to survive; sometimes, the victim and his or her family need someone to blame, and an attorney may be readily available to exploit raw emotions. The time element is the fourth possible loss category and includes the cost of renting equipment or the time damaged equipment cannot be used until it is repaired.

During risk-management planning, there are many choices to be made, some of which are difficult, while others are clear and precise. The best method of making choices is to have as much data and research information as possible about the subject. There are times when the data will be clear, but the choice may not be clear. All choices involve responsibilities and consequences and, since a decision must be made and implemented through training or a written standard operating procedure, all consequences must be thoroughly examined. The personnel or procedure most affected by a new decision or a changing decision must be considered, and discussion with the appropriate personnel should occur so that all sides of the issues and possible circumstances are delineated prior to implementation.

Some of the results obtained from a sound risk-management program include (Andrews 2004):

- The emergency organization may survive a major loss rather than be put out of business.
- The organization achieves a bottom line where the income is still greater than the expenses. Even though most emergency organizations are nonprofit-based, they still need to handle their expenses just as if they were a for-profit organization. Contributions and charity events are usually the main source of income if the local government has problems devoting operating funds through real estate taxes.
- Emergency service organizations must be available 24 hours a day, 7 days a week. Keeping equipment in good repair means that no emergencies may need to be rerouted to another organization for help until lost or damaged equipment is returned to service.
- The risk-management program is similar to a for-profit corporation's budget. The emergency organization needs to prepare and anticipate any stable expenses for its operating year.
- The management of losses will not impede the growth of the organization, and the organization should maintain good relations with the public it serves.
- As with any process of risk management, all critical areas such as laws, regulations, and standards must be included in the finished program. Compliance is a major factor in any completed and implemented risk-management program.

When starting a risk management plan (RMP), a company must begin by consulting with all applicable parties to obtain their input, such as the legal department, the safety department, and drivers (and the union if warranted). If the business is local or regional, the state's regulations must be considered; if it is national, all appropriate regulations must be included.

Traffic Safety Principles

Highway Safety and Roadway Geometry

Highway safety is the responsibility of everyone, and safety elements must be reviewed, updated when necessary, and used for training. Management must begin by setting standards, showing employees how to meet the standards, evaluating the safety efforts, and giving recognition or additional training when needed.

Roadway geometry plays an important part in safety and must be considered each time roads are built or improved. Roadway design usually includes the travel portion of the roadway, shoulders or emergency escape path, alignment, and intersecting roadway safety. There are many references on the subject, including the American Association of State Highway and Transportation Officials' "Policy on Geometric Design of Highways and Streets" (AASHTO 1990), the *Manual on Uniform Traffic Control Devices* (DOT 2000), and the *Traffic Engineering Handbook* (ITE 1999). These publications provide detailed standards and best practices relating to roadway geometry. Design guides should also be used as references for driver training.

A railroad-track grade crossing is a special type of highway intersection where three elements converge: the driver, the vehicle, and the physical intersection. At a typical motor-vehicle intersection, drivers take turns yielding to opposing traffic, but at railroad grade crossings, trains are the opposing traffic, and they rarely yield right-of-way to motorists. Motor-vehicle operators can change their path and alter their speed, whereas trains have a fixed path and change speed much more slowly. Fleet-vehicle operators must be aware of the difference between a typical roadway intersection and a railroad grade crossing. At a railroad grade crossing, the vehicle operator bears most of the responsibility for avoiding a collision with a train. The railroad crossing crossbuck is a yield sign, and the motor-vehicle operator must interpret it as such (Southhall 1961, 273).

The Uniform Vehicle Code (NCUTLO 2000) is a model for motor-vehicle laws that indicates actions drivers are required to take at railroad crossings. This code states, in section 11/701, that when a driver of a motor vehicle approaches a rail highway crossing under the following circumstances, he or she shall stop the vehicle within fifty feet of but not less than fifteen feet from the nearest rail and shall not proceed until it is safe to do so (Southhall 1961, 275):

- A clearly visible electric or mechanical signal indicates the approach of a train.
- A crossing gate is lowered or the presence of a human flagman gives or continues to give the signal of an approaching train.
- A train approaching within 1500 feet of the highway crossing gives an audible signal.
- The approaching train is clearly visible and presents a hazardous condition.

Fleet drivers must also be aware of the various decision zones relating to railroad crossing hazards:

- The *approach zone* is an area in which drivers must begin to formulate their actions in order to avoid a collision. In this zone drivers look ahead and determine whether a train is nearby or present.
- The *nonrecovery zone* is the area in which drivers begin to stop if a train is crossing or approaching as well as being cautious and looking left and right for additional information if a train is not immediately perceived.
- The final zone is the *hazard zone.* In this zone, drivers must stop if a train is crossing or approaching and also must decide whether or not to go across the tracks. If there is no train present, drivers must look both ways before crossing the tracks.

Vehicle type is another component of decisions made at railroad crossings. A passenger vehicle that has acceleration and deceleration superior to that of a truck can cross railroad tracks much more quickly than a truck. The length of the truck, its braking ability, and its acceleration are important in determining whether a truck driver can cross tracks safely. Longer and heavier trucks must be considered when designing railroad crossings with respect to these factors:

- *Sight distance* (A longer sight distance is needed for trucks due to their slower deceleration and handling compared to passenger vehicles.)
- *Placement of advanced warning signs* (They must be far enough away that trucks have time to stop.)
- *Train warning whistles* (Whistles must be sounded in time for trucks to hear them and stop.)
- *Sight lines of approach and departure grates* (Truck drivers must be able to see them in time to react and stop.)

When approaching railroad crossings, truck operators must consider the type of road, the traffic volume, the angles and geometry of the crossing, the presence of nearby intersecting roadways, and the illumination. They must never be impatient or attempt to cross in front of an oncoming train.

Passing Sight Distance

Greater sight distance is required for one vehicle to pass another in the lane normally reserved for opposing traffic on a two-lane highway than is required simply to bring a vehicle to a stop before reaching an object in the road. Table 7 presents the passing sight-distance criteria used

TABLE 7

Design Criteria for Stopping Sight Distance

Design Speed (mi/h)	Minimum Stopping Sight Distance Used in Design (ft)
15	80
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645
70	730
75	820
80	910

Note: Brake reaction distance predicated on a time of 2.5 s; deceleration rate of 11.2 ft/s^2 used to determine calculated sight distance

(*Source:* TRB 1997)

in geometric design, and the criteria used in marking of passing and no-passing zones on two-lane highwaysis shown in Table 8. The geometric design criteria are more conservative than the marking criteria, but neither is based on a completely consistent set of assumptions.

The current passing sight-distance criteria shown in Table 7 were derived on the basis of passenger-car behavior and do not explicitly consider heavy vehicles. Using a new sight-distance model with more consistent assumptions, Harwood et al. derived sight-distance requirements for various passing scenarios involving passenger cars and trucks, as shown in Figure 9 (TRB 2008). The figure indicates that all passing scenarios are accommodated within the current geometric design criteria. Furthermore, Harwood et al. also found that a truck can safely pass a passenger car on any crest vertical curve on which a passenger car can safely pass a truck (see Figure 10). The current marking criteria for passing and no-passing zones do not necessarily accommodate all passing maneuvers that truck drivers might wish to make (TRB 2008).

However, there is currently no indication that the passing and no-passing zone markings lead truck drivers to make poor passing decisions, or that trucks are over-involved in passing-related accidents. Thus, there is no indication that a change in marking criteria to better accommodate trucks would have safety benefits. There is concern that such a change could eliminate some passing zones that are currently used effectively by passenger cars. Further research on this issue is needed.

TABLE 8

Design and Marking Criteria for Passing Sight Distance

Design or Prevailing Speed (mi/h)	Highway Design[a]	Marking of Passing and No-Passing Zones[b]
25	900	450
30	1090	500
35	1280	550
40	1470	600
45	1625	700
50	1835	800
55	1985	900
60	1985	900
65	2285	1100
70	2480	1200

[a]*Based on AASHTOGreen Book.*
[b]*Based on MUTCD.*

(*Source:* TRB 1997)

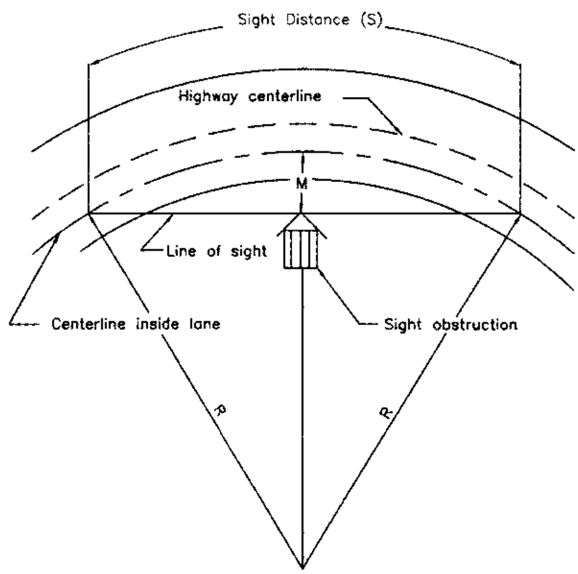


FIGURE 10. Application of stopping sight distance to horizontal curves (*Source:* TRB 1997)

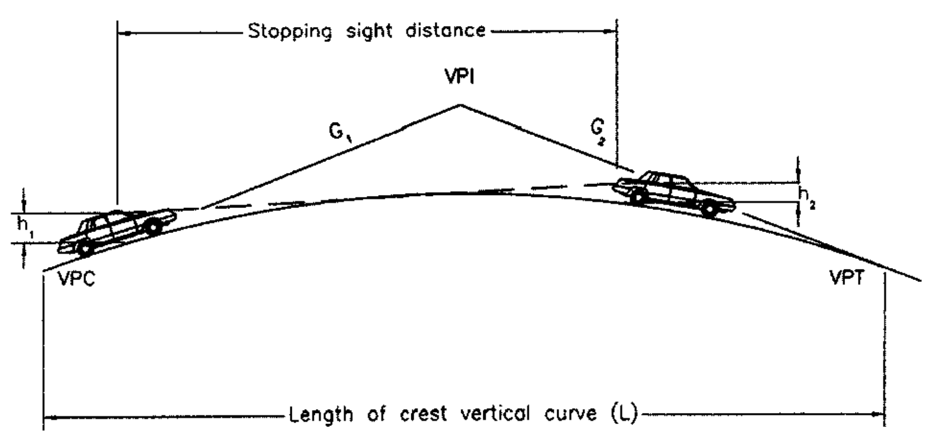


FIGURE 9. Application of stopping sight distance to crest vertical curves (*Source:* TRB 2008)

Fleet Statistics

It is important for fleet managers to keep statistics because they can demonstrate the proficiency of fleet drivers with regard to avoidable and unavoidable accidents. Statistics also assist the maintenance department in creating vehicle maintenance schedules. Accident and injury statistics such as data compiled for large trucks and buses in the State of New Jersey for 2001–2005 (Tables 9 and 10) can also demonstrate the effects of efforts toward safety; but, in and of themselves, they cannot achieve a reduction in injuries. Statistics are a snapshot taken at one point in time that can guide safety managers in continuing or developing fleet safety programs. These programs can include regular driver-safety updates as well as safety at loading and unloading docks and warehouse facilities. According to the National Highway Traffic Safety Administration, motor vehicle crashes and fatalities increased in 2012 after six consecutive years of declining fatalities on our nation's highways (NHTSA November 2013). Statistical graphs of the type shown in Figures 11–16 for large trucks and buses are a valuable asset for review and are especially useful in determining whether a company is keeping up with or doing better than its state or the nation in controlling injuries and deaths. These statistics are for New Jersey, but statistics for each state and the nation are available online at www.ai.volpe.dot.gov/crashprofile/crashprofilemainnew.asp. [*NOTE:* For Tables 9 and 10 and Figures 11 through 16, Fatality Analysis Reporting

TABLE 9

Summary of Large Trucks Involved in Crashes (New Jersey)

Number of Large Trucks Involved in:	Year 2001	2002	2003	2004	2005
Fatal and nonfatal crashes (FARS & MCMIS)	7735	6928	7741	7893	NA
Fatal crashes (FARS)	76	69	85	87	NA
Fatal crashes (MCMIS)	73	39	61	87	66
Nonfatal crashes (MCMIS)	7659	6859	7656	7806	6680
Injury crashes (MCMIS)	3653	3176	3547	3500	2851
Towaway crashes (MCMIS)	4006	3683	4109	4306	3829
HM placard crashes (FARS & MCMIS)	0	0	2	3	NA
Fatalities (FARS)	77	72	75	79	NA
Injuries (MCMIS)	5358	4694	5171	4979	4154

The MCMIS crash file is intended to be a census of trucks and buses involved in fatal, injury and towaway crashes; however, some states do not report all FMCSA-eligible crashes. FMCSA continues to work with the states to improve data quality and reporting of all eligible truck and bus crashes to the MCMIS crash file.

(*Source*: FMCSA Analysis and Information Online 2006)

TABLE 10

Summary of Buses Involved in Crashes (New Jersey)

Number of Buses Involved in:	Year 2001	2002	2003	2004	2005
Fatal and nonfatal crashes (FARS & MCMIS)	1282	1024	1182	1197	NA
Fatal crashes (FARS)	10	13	10	10	NA
Fatal crashes (MCMIS)	7	8	6	8	8
Nonfatal crashes (MCMIS)	1272	1011	1172	1187	1034
Injury crashes (MCMIS)	713	574	624	656	554
Towaway crashes (MCMIS)	559	437	548	531	480
HM placard crashes (FARS & MCMIS)	0	0	0	0	NA
Fatalities (FARS)	12	14	11	11	NA
Injuries (MCMIS)	1379	1149	1223	1309	990

The MCMIS crash file is intended to be a census of trucks and buses involved in fatal, injury and towaway crashes; however, some states do not report all FMCSA-eligible crashes. FMCSA continues to work with the states to improve data quality and reporting of all eligible truck and bus crashes to the MCMIS crash file.

(*Source*: FMCSA Analysis and Information Online 2006)

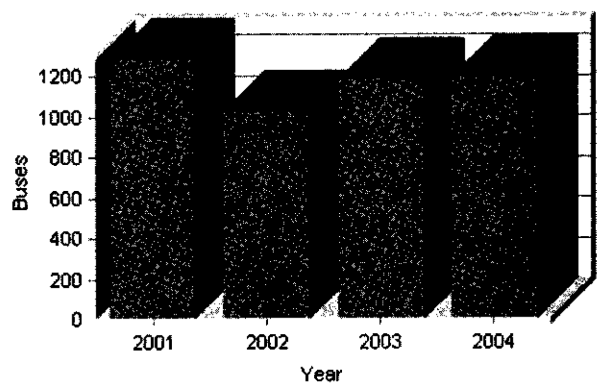


FIGURE 11. Number of buses involved in fatal and nonfatal crashes (FARS and MCMIS) in New Jersey (*Source:* FMCSA Analysis and Information Online 2006)

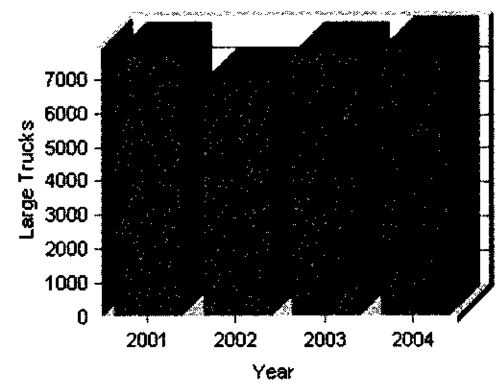


FIGURE 12. Number of large trucks involved in fatal and nonfatal crashes (FARS and MCMIS) in New Jersey (*Source:* FMCSA Analysis and Information Online 2006)

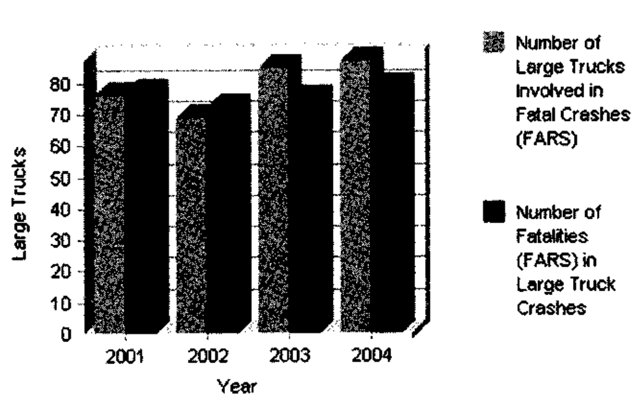


FIGURE 13. Number of large trucks involved in fatal crashes in New Jersey (*Source:* FMCSA Analysis and Information Online 2006)

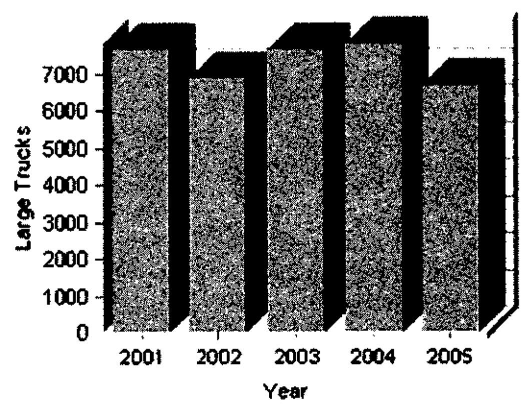


FIGURE 15. Number of large trucks involved in nonfatal crashes in New Jersey (MCMIS) (*Source:* FMCSA Analysis and Information Online 2006)

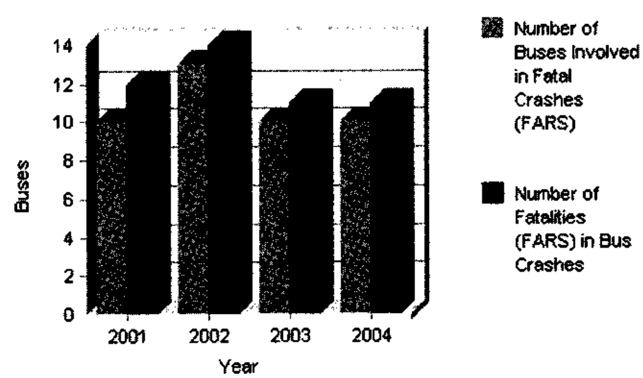


FIGURE 14. Number of buses involved in fatal crashes in New Jersey (*Source:* FMCSA Analysis and Information Online 2006)

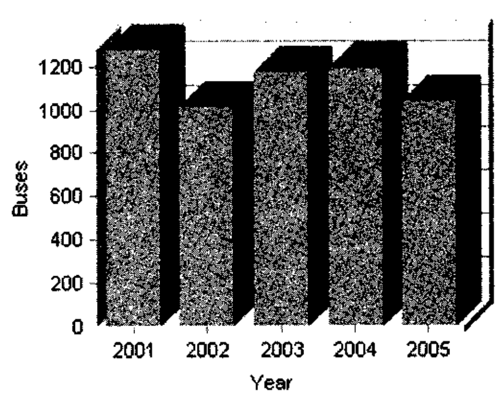


FIGURE 16. Number of buses involved in nonfatal crashes in New Jersey (MCMIS) (*Source:* FMCSA Analysis and Information Online 2006)

System (FARS) and Motor Carrier Management Information System (MCMIS) data are from March 2006. FARS data from 2005 are not available.]

Injury Crashes

From 2007 to 2011, the number of large trucks involved in injury crashes per 100 million vehicle miles traveled declined by six percent, while the rate for passenger vehicles dropped by eight percent (see Figure 17).[1]

One notable statistic shows that passenger vehicles far surpass large trucks in injuries per million miles traveled, but large trucks outnumber passenger cars in deaths (Figure 18). It is no surprise that large-truck death figures surpass those of passenger vehicles since the results of an impact between a large truck and a passenger vehicle normally are weighted against the passenger vehicle. Statistics such as these are of great importance to a safety analysis, and statistics generated regarding a company's own fleet are even more meaningful. Committees that decide whether accidents are preventable or not can use statistical information such as this along with specific facts surrounding the accidents.

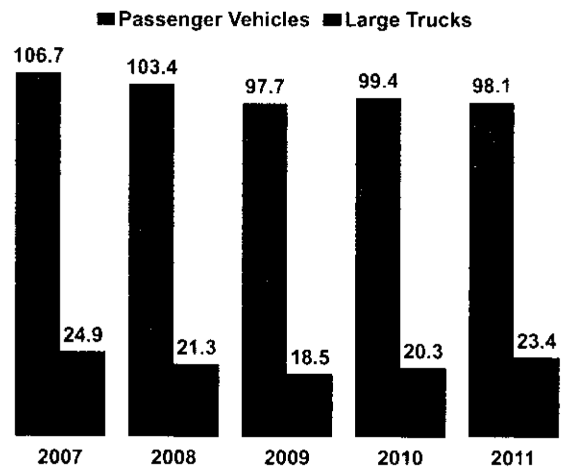


FIGURE 17. Vehicles involved in injury crashes per 100 million vehicle-miles traveled (*Source:* FMCSA 2013)

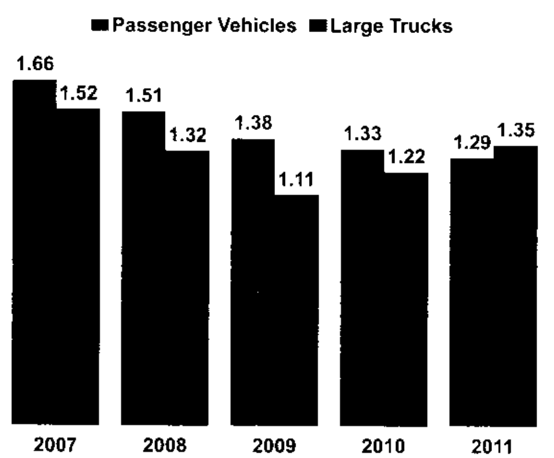


FIGURE 18. Vehicles involved in fatal crashes per 100 million vehicle-miles traveled
(*Source:* FMCSA 2013)

[1] The downward trend continues with the FHA reporting a vehicle involvement rate of 35.67 for large trucks in 2012 (NHTSA 2014).

Work-related roadway accidents kill more employees each year than any other occupational cause of death. In addition to the devastating human toll to employees, communities, and families, companies face massive productivity losses and soaring medical and workers' compensation costs. Michael Deak, safety director at DuPont in Wilmington, Delaware, stated, "If a worker is injured driving their own vehicle or driving a fleet vehicle, the cost is the same to us." In an attempt to counter the high productivity cost as a result of accidents, OSHA is bringing more agency resources to bear on the problem of occupational driving fatalities (Deak 2004, 44–48).

Increasingly, employers are instituting their own internal driving standards, procedures, and regulations covering subjects from seatbelts to fleet vehicle selection and use of personal vehicles on company business. DuPont has outlined driving standards for vehicle safety which include procedures for driver training as well as for auditing and measuring the results (Deak 2004, 44–48). Some believe that statistically, the more moving violations or preventable crashes a driver has, the greater the chance he or she will be involved in a catastrophic crash (Deak 2004, 44–48). It is believed that people with no moving violations on their driving record have been careful. Some insurance carriers check driving records of those who drive company-owned vehicles quarterly and assign a point system for moving violations and preventable crashes. When a driver reaches a certain level of points, action is taken to improve his or her performance.

A study completed by the National Institute of Occupational Safety and Health (NIOSH) in 2004 determined that 28 percent of workers fatally injured while driving a vehicle were wearing seatbelts, and 56 percent were unbelted or had no seatbelt available. OSHA, in its movement toward creating driving standards, indicates that in 2001 approximately 4.2 million workers drove a motor vehicle on the job. They ranged from long-haul truckers to pizza deliverers and from school bus drivers to salespersons. Between 1992 and 2001 over 13,000 workers died in crashes. The statistics bear out the need for fleet training as well as constant monitoring of drivers and driver records (see Tables 11 and 12 and Figures 19 through 24).

TABLE 11

National Summary of Large Trucks Involved in Crashes

Number of Large Trucks Involved in:	Year 2004	2005	2006	2007	2008
Fatal and nonfatal crashes (FARS & MCMIS)	139,345	147,202	147,149	147,697	132.,791
Fatal crashes (FARS)	4902	4951	4766	4633	4066
Fatal crashes (MCMIS)	4848	5240	4967	4808	4169
Nonfatal crashes (MCMIS)	134,433	142,251	142.,383	143,064	128,725
Injury crashes (MCMIS)	60,796	61,777	60,248	58,089	51,147
Towaway crashes (MCMIS)	73,647	80,474	82,135	84,975	77,578
HM placard crashes (MCMIS)	2453	2574	2278	2296	2630
Number of:					
Fatalities (FARS)	5235	5240	5027	4822	4229
Injuries (MCMIS)	85,023	86,642	84,199	80,098	70,567

The MCMIS Crash File is intended to be a census of trucks and buses involved in fatal, injury and towaway crashes; however, some States do not report all FMCSA-eligible crashes. FMCSA continues to work with the States to improve data quality and reporting of all eligible truck and bus crashes to the MCMIS crash file.

(*Source*: FMCSA Analysis and Information Online 2009)

TABLE 12

National Summary of Buses Involved in Crashes

Number of Large Trucks Involved in:	Year 2004	2005	2006	2007	2008
Fatal and nonfatal crashes (FARS & MCMIS)	9181	11,148	12,514	13,529	14,089
Fatal crashes (FARS)	279	280	305	281	247
Fatal crashes (MCMIS)	210	5240	273	260	257
Nonfatal crashes (MCMIS)	8902	249	12,209	13,248	13,842
Injury crashes (MCMIS)	5224	10,868	6912	7143	7491
Towaway crashes (MCMIS)	3678	6140	5297	6105	6351
HM placard crashes (MCMIS)	0	8	10	11	11
Number of:					
Fatalities (FARS)	315	340	337	325	307
Injuries (MCMIS)	12,368	14,426	15,466	15,633	16,935

The MCMIS Crash File is intended to be a census of trucks and buses involved in fatal, injury and towaway crashes; however, some States do not report all FMCSA-eligible crashes. FMCSA continues to work with the States to improve data quality and reporting of all eligible truck and bus crashes to the MCMIS crash file.

(*Source*: FMCSA Analysis and Information Online 2009)

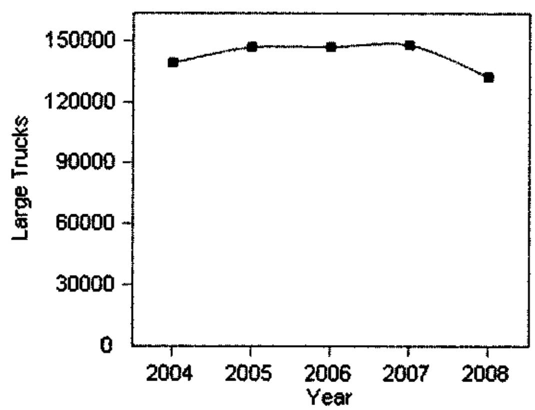


FIGURE 19. Number of large trucks involved in fatal and nonfatal crashes (*Source:* FARS and MCMIS 2009)

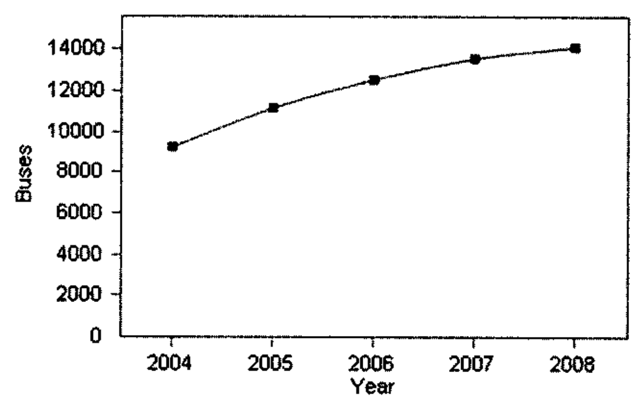


FIGURE 20. Number of buses involved in fatal and nonfatal crashes (*Source:* FARS and MCMIS 2009)

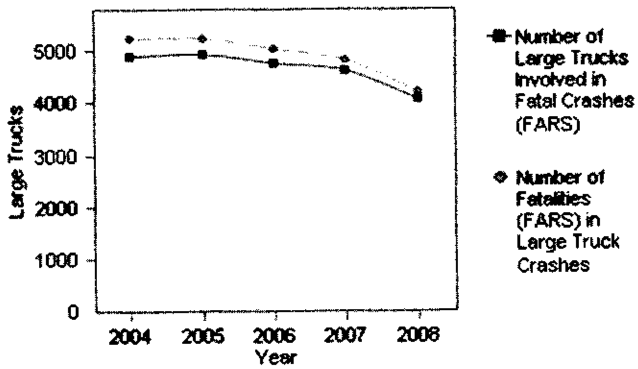


FIGURE 21. **Number of large trucks involved in fatal crashes** (*Source:* FARS and MCMIS 2009)

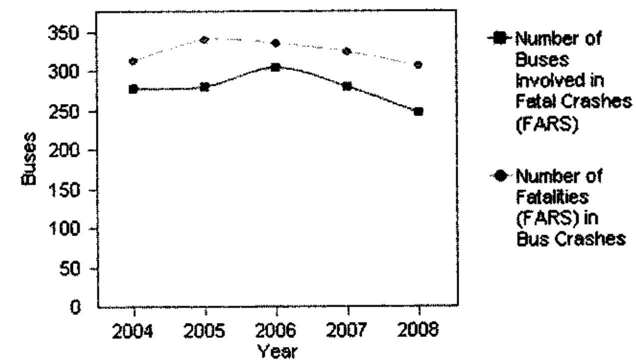


FIGURE 22. **Number of buses involved in fatal crashes** (*Source:* FARS and MCMIS 2009)

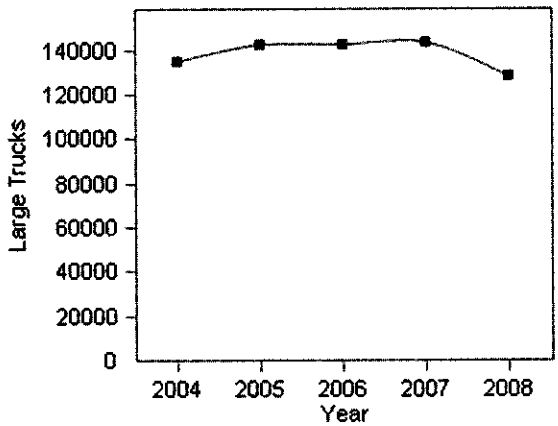


FIGURE 23. **Number of large trucks involved in nonfatal crashes** (*Source:* FARS and MCMIS 2009)

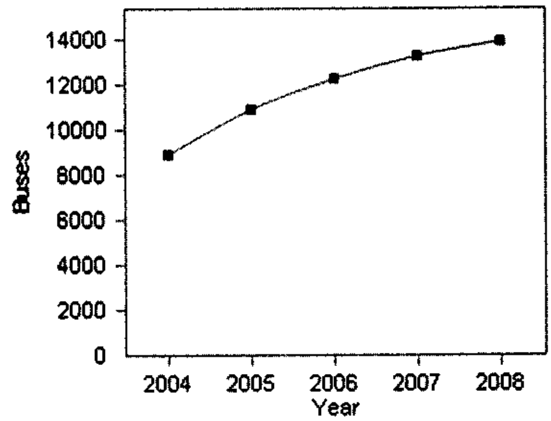


FIGURE 24. **Number of buses involved in nonfatal crashes** (*Source:* FARS and MCMIS 2009)

Note: Although efforts have been made to provide the most accurate and complete MCMIS crash data possible, data quality can vary from state to state. Please use caution when interpreting MCMIS crash data.

Nighttime Driving and Vision

Safety issues when it is dark involving nighttime driving require special evaluation and action since the visibility and acuity is are critical to safe driving. Reaction time is considerably slower at night than during the day (Allen 1996, 201–238). The human eye sees using rods and cones. *Rod* vision is known as *scotopic* vision, while *cone* vision is *photopic* vision. Scotopic vision is the vision a driver uses during nighttime driving. Photopic vision is used for acuity and to distinguish between colors. The level of nighttime lighting on roadways is below what is necessary for photopic vision. At night the human eye relies on the more sensitive 125 million rod cells, usually seeing shades of gray or black, which explains why it is difficult for someone to see an object that is not fully illuminated. Daytime vision is performed with cones, which comprise approximately 5.5 million cells. They allow for quicker identification of colors and possible hazards than rods, which do not distinguish between colors except for shades of gray and black.

State traffic regulations require visibility at certain distances when using illuminated headlamps: 250 feet on low beam and 500 feet on high beam. Therefore, on low beam a driver needs to know what is ahead within the next 250 feet, and in order not to overdrive the headlights he or she must consider the vehicle's speed, the road conditions, and his or her own acuity. Perception and reaction times are believed by some to be a minimum of 1.5 seconds for a single emergency maneuver. This 1.5-second perception-reaction time is controversial because some perception-reaction studies allow drivers to know that they will be expected to react to an object, and consequently their attention is high—usually higher than that of a typical driver with no idea a hazard may lie ahead. The 1.5 seconds may be accurate for one reaction, such as braking, to an expected emergency, but it does not include more complicated perception, evaluation, and reaction sequences in reaction to different types of unexpected hazards, so nighttime perception and reaction times could be much greater than this value.

The *Manual on Uniform Traffic Control Devices* (DOT 2000, 2A-19) uses a standard of 2.5 seconds for simple reaction and perception times. Of course all drivers are different, and to use an exact figure would be inconsistent with good engineering judgment. It would be best to use a range for perception and reaction times depending upon the specific accident issues being investigated. For example, one would not use the same time for a simple emergency braking maneuver for a driver who requires more information to make an appropriate safety maneuver and is traveling closer to the hazard while acquiring the information.

Nighttime visibility involves many factors, including brightness and contrast. *Brightness* is the reflection off an object from light falling on the object, and *contrast* is the difference in brightness between an object and its background. At night, if pedestrians wear dark clothing and there is no backlighting, even an alert driver will find it difficult to spot them soon enough to avoid impact. There are many other reasons for poor nighttime visibility, including dirt on the inside and outside of the windshield, dirty headlamps, inattention, and so on.

Research has been a valuable tool in alerting drivers to the problems of nighttime driving. It has found that light clothing is preferable to dark clothing and that visibility is better if some portion of the clothing is made of reflective material. Tests have also shown that fog creates a substantial driving hazard because light reflects off the water droplets and returns directly to the eye of the driver. The driver's level of expectancy or attention also plays a critical part in detection of hazards during nighttime driving (Shinar 1985, 243–245).

The driver's limit of vision varies outside of the accurate vision area (one degree on either side of the centerline of the eyes). The word recognition limit for signs occurs between 5 and 10 degrees, and the symbol recognition limit is between 5 and 30 degrees from the centerline of the driver's eyes while facing forward. Limits for locating emergency controls within the truck cab are between 30 and 60 degrees. Cleaning the cab interior, especially the lens caps of instruments, as well as a routine maintenance program for replacing instrument bulbs, adds to the safety of the driver (Marshall 2000, 376–380).

Sensitivity to contrast is the ability of the human eye to perceive a small difference in luminance. Visual acuity—the ability to detect small details and small objects—decreases with age: the visual acuity of an 80-year-old is approximately 50 percent that of a 20-year-old. Contrast sensitivity is more important than visual acuity for many jobs such as inspection and product control. Speed of perception and contrast sensitivity are closely connected to each other and must be maintained for safe driving at night (Kroemer 1999, 275–282).

On December 10, 1992, the National Highway Traffic Safety Administration (NHTSA) published a final rule requiring that trailers manufactured on or after December 1, 1993, which have an overall width of 2032 mm (80 inches) or more and a gross vehicle weight rating (GVWR) of more than 4536 kg (10,000 pounds), except pole trailers and trailers designed exclusively for living or office use, be equipped on the sides and rear with a means for making them more visible on the road.

The NHTSA rule allows trailer manufacturers to install either red and white retroreflective sheeting or reflex reflectors. Manufacturers of retroreflective sheeting or reflectors are required to certify compliance of their product with Federal Motor Vehicle Safety Standard (FMVSS) No. 108 (49 CFR 571.108), whether the product is for use as original or replacement equipment. The manufacturer's certification will consist of one of the following markings, depending on the type of conspicuity material:

- DOT-C: Rectangular reflex reflectors certified as meeting the standard.
- DOT-C2: 50 millimeter (mm) wide retroreflective sheeting material certified as meeting the standard.
- DOT-C3: 75 mm wide retroreflective sheeting certified as meeting the standard.
- DOT-C4: 100 mm wide retroreflective sheeting certified as meeting the standard.

Currently, Section 393.11 requires that all lamps and reflective devices on motor vehicles placed in operation after March 7, 1989, meet the requirements of FMVSS No. 108 in effect on the date of manufacture. Therefore, trailers manufactured on or after December 1, 1993, must have reflective devices of the type and in the locations specified by FMVSS No. 108, including the conspicuity treatments.

If you plan on driving after the sun goes down, it is important to remember that driving at night presents different challenges than driving during the day. Traffic death rates are three times greater at night, yet many of us are unaware of the hazards that night driving poses or of effective ways to handle them.

At night, vision is severely limited. Drivers lose the advantage of color and contrast that are available during the day, and depth perception and peripheral vision are also diminished.

To improve night vision and driving ability after sunset, the Motor Vehicle Lighting Council (MVLC) offer drivers these tips (MVLC 2009):

1. ***Use your lights courteously.*** Turn your headlights on one hour before sunset to make it easier for other drivers to see you in early twilight. Keep your headlights on at least one hour after sunrise. Refrain from flashing your high beams at a vehicle with its high beams on; this will only increase the chance that drivers will not be able to see. In fog, use low-beam headlights; high beams reduce your own ability to see and may temporarily blind other drivers. If your vehicle is equipped with fog lamps, use them with your low beams only when there is fog or inclement weather.
2. ***Make it easy for others to see you.*** Be sure that all exterior vehicle lights work properly. In case of a vehicle breakdown, pull completely off the road beyond the end of the guardrail, if possible, and turn on the emergency flashers.
3. ***Avoid glare.*** Instead of looking at oncoming headlights, look toward the right side of the road and watch the white line marking the outside edge of the traffic lane. When headlights from vehicles following you reflect in your rearview mirror, use the "day-night" feature on the mirror or adjust your mirror to cut out as much of the light as possible.
4. ***Adjust your vehicle's interior lighting.*** If streetlights cause a lot of glare, dim your dashboard lights and use your sun visor. Avoid using any other light inside your vehicle.
5. ***Keep all windows and headlights clean.*** Dirty windows can increase glare, making it more difficult to see, while dirty headlights can reduce efficiency by as much as 90 percent. Be sure to clean the inside and outside of your windshield as well as your headlights.
6. ***Keep your eyes moving.*** Look for flashes of light at hilltops, curves, and intersections that may indicate the headlights of other vehicles.
7. ***Increase your following distance.*** Increasing your distance by four to five seconds can make it easier to spot potential problems on the roadway and gives you more time to respond. In addition, proper lighting will enable you to react quicker and stop at a safe distance from the vehicle in front of you.
8. ***Regulate speed.*** Driving too fast is more dangerous after dark than during the day because of decreased visibility. Traveling at high speeds does not allow you enough time or distance to stop when you see something dangerous on the road ahead.
9. ***Prevent fatigue.*** Night driving can be tiring, so ensure good ventilation inside the vehicle and take frequent refreshment breaks to give your eyes a chance to recover. Take a short nap or a brisk walk, or have some caffeine to help you stay alert.
10. ***Use vehicle mirrors to your advantage.*** Exterior mirrors that are properly aligned not only reduce blind spots, they also reduce glare from vehicles behind you. The outside rearview mirrors should be adjusted so that the bodywork of the vehicle is just outside of the driver's view. In addition, the rearview mirror can be flipped to its "day-night" setting, which changes the angle of the reflective surface and appears to dim the mirror.

In addition, there are also some general practices one can follow to help ensure safe night driving:

1. ***Align your headlights correctly.*** Properly aligned headlights will help you see the road better and will help other drivers avoid glare. If you live in a state that requires regular safety inspections, ask the service technician to check and correct the aim of your headlights. If your state does not require such an inspection, take your vehicle to a dealer or repair shop at least once a year for a headlight checkup.
2. ***Have your vision checked regularly.*** The American Optometric Association recommends that everyone under the age of 40 have a thorough eye exam at least every three years; drivers 41–60, every two years; and drivers over 60, every year. Age can make eyes more sensitive to glare. In addition, certain medical conditions, such as encroaching cataracts, will increase eye sensitivity.
3. ***Look into antireflective eyeglass coating.*** Many eye-care professionals strongly recommend eyeglasses that have an antireflective (AR) coating. This ultra-thin film reduces internal reflections in the lenses. AR-coated glasses actually transmit more light than regular lenses, which improves vision at night and helps distinguish fine details during the day.

Work Zone Safety

Good safety professionals are acutely aware of safety in roadwork zones. Safety is also an important consideration when the work involves closing lanes or complete roadways due to emergency events. Safety in work zones is and has been crucial to the protection of public employees and emergency responders. Work-zone setup or design is based on the regulations found in the *Manual on Uniform Traffic Control Devices* (DOT 2000, ch. 6) and 29 CFR 1926.21 and .200. These regulations define and guide the proper placement of signs, markings, barriers, flaggers, and so on.

Safety professionals should be cognizant of three terms used throughout these manuals and regulations:

- *Shall* means that use of a device or practice is mandatory.
- *Should* means the device or practice is recommended but not mandatory.
- *May* means the device or practice is not required by regulation.

Work zones are planned and designed according to the type of work to be done, the location, characteristics of the roadway, and the length of time the work will take. For example, if a work zone requires closing one lane of a multilane roadway, signs of different kinds are installed at various distances before and after the actual work area. Regulations are specific regarding the use of the devices mentioned earlier, and the placement of warning devices is also dictated by regulation. The purpose of the warnings is to allow drivers to pass work areas safely and without incident. In some locations, such as on interstate highways, the first notice of the impending work area is a sign approximately one mile from the traffic cones that taper the traffic into other lanes if one lane is closed.

Typical equipment used at a work zone includes standard orange cones, lighted and flashing signs, crash-cushion trucks, and human flaggers. Flaggers are normally used on single-lane roadways where traffic is stopped in one direction to allow traffic from the opposite direction to pass through the work area. Alternating traffic through this work area is the prime concern of the flagger. The placement of traffic-control devices such as signs is important, since they can create hazards within the roadway and can be hazards themselves. Signs must be temporary in work zones of short duration or be made to break away in more permanent installations. Traffic-control devices used in work zones are different from those used for standard traffic control, but the goal is the same: safety of the traveling public and pedestrians.

Several principles and procedures must be considered when designing a safe work zone. If the work is to continue for a number of days or weeks, traffic-control devices are more permanent in nature, especially if the roadway remains in repair over this period of time! Many accidents that occur in work zones are contributed to by inattentive drivers. Work zones must be planned well in advance so that proper notice and guides for drivers are in place. One of the most common violations of work-zone design is the lack of appropriate advanced notice to drivers of the impending work area. Work-zone design for nighttime driving must include more highly visible warnings, such as lighted signs, so the attention of nighttime drivers will be drawn to the warnings.

The following factors are important for work-zone safety:

- Traffic safety is a high priority in every emergency or work zone. Every element regarding planning and design must be thoroughly analyzed and a sound and safe plan properly implemented.
- Traffic movement is the main element to consider when designing a work zone since the traffic that must pass through the work zone is the number one hazard to both workers and other traffic.
- *Traffic guidance* is the method whereby motorists are guided on a safe travel path through and around a work zone. The guidance must include daytime and nighttime traffic-control devices and must consider the human factors of the majority of drivers.
- Inspection of the work zone is imperative for continuous safe operation. Once a work zone is designed and the design is implemented, the traffic-control devices must be constantly monitored for consistent expectancy and safe operation. The work zone must be inspected during both daytime and nighttime operation.
- Maintenance of the work zone needs constant attention during the period the work zone is active because hazards may change from time to time.

Work zones must be analyzed by considering the type and location of work being performed, the expected life of the work zone, the type of roadway, and the traffic speed and volume. The location of the work zone is important because the design for a highway is not applicable to all situations, especially inner-city work zones. Shoulders and lane widths must be considered in the design of new traffic patterns as well as traffic volume during various times of day.

Signs and other control devices should be consistent for all work-zone areas so that drivers know what to expect. The colors and sizes of signs specified by regulation must be adhered to since drivers expect certain types of signs to be a certain size and color. Various types of tubular markers and barricades are designed to alert drivers at various stages as traffic flows through a work zone. Flaggers should be used when traffic is compressed into a single lane so that traffic congestion and accidents are reduced or eliminated.

The training of flaggers must be consistent with regulations, and any deviation from the standards and expectancies of the traveling public should be eliminated. Flashing traffic-control devices that alter traffic patterns must be set up at the minimum distance required. If the warning distance is insufficient for drivers to alter their travel pattern in time, accidents and congestion can develop. During any traffic-pattern change, traffic signs, especially route signs and detour signs, become crucial.

Defensive Driving Tactics

Weather-Related Safety

In addition to darkness, weather (high winds, snow and rain, dust storms, and so on) is a key factor contributing to accidents and injuries. Under the best dry conditions, posted speed limits can be used to regulate speed, but when weather conditions are adverse, speed limits no longer should be used as a guideline. Large tractor-trailers are especially vulnerable to poor weather conditions; they may jackknife under slippery surface conditions or be blown off the road during high winds. During long hauls, driver fatigue sets in, and if this is coupled with adverse weather, the driver's attention and precision are drastically reduced. Frequent stops will help with fatigue, and drivers should stop and sleep when necessary.

Weather can affect the mechanics of vehicles too:

- Moisture in air-brake bleed-off tanks (drain moisture) can freeze and lock the brakes if not drained properly.
- Antifreeze must be appropriate for anticipated temperatures; it should be adequate for a lower temperature range than anticipated in case there is an extreme cold snap.
- During winter months when snow or slush is on the roadway, windshield wipers and washers must work properly, and washer fluid must be antifreeze protected. Dirty windshields may cause vision problems and accidents.
- Headlamps must be kept clear during nighttime use, and if the roadway is covered with rain or snow, they must be cleaned periodically during a long trip.
- On slippery surfaces, it is easy to lose traction, so drivers must accelerate slowly and with light foot pressure.
- Most commercial vehicles, state regulations permitting, may use chains or studded tires on their drive axle. They work well on snowy roadways, but on dry roadways, they produce less friction (stability) than standard tires do.
- During adverse weather conditions, stopping and braking efficiency are reduced. Adjusting speed will improve these problems, but increasing the following distance behind other vehicles is also critical in order to stop safely.
- During turns in poor weather, a gentler and slightly wider turn, if possible, should be made since cutting a turn sharply in adverse weather will exacerbate poor handling and possibly cause accidents and injuries.
- Drivers must not drive through water above the vehicle's brake lining, since wet brakes will dramatically reduce stopping distance.

Pretrip Vehicle Examination

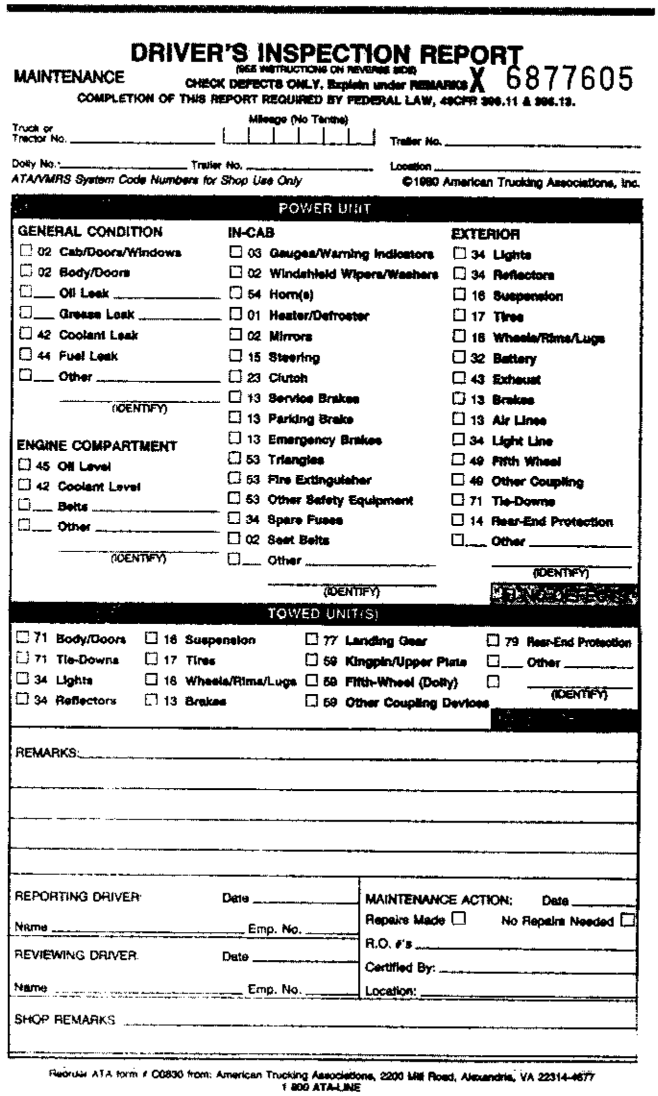
A pretrip inspection should be performed each time a driver begins a trip. A thorough pretrip inspection to catch operational problems is a defensive driving practice since it is an active step compared to waiting until a problem arises. Drivers doing pretrip inspections may identify defective safety devices or worn parts prior to driving on the road, thereby avoiding an accident or injury. Inspections are designed so that the operator can spot system problems prior to an actual failure. Specifically, the following items should be checked to make sure they are working properly prior to starting out on a trip (ATA 1996, 46):

1. Service brakes, including couplings between tractors and trailers, should be inspected for cracks or holes. The hoses can rupture or crack because of changes between one climate and another, and the ensuing loss of brake fluid or air pressure could be critical.
2. The parking brake should be inspected to determine whether it is working properly. If the service brakes do not function, this is the driver's last line of defense.
3. The steering mechanisms must be examined for unusual noise or friction, and if there is a problem, a determination must be made regarding its seriousness. An examination of the steering mechanism by a garage mechanic is not warranted at the start of each trip; this type of detailed inspection is done during regular maintenance.

4. The horn, windshield wipers, and rearview mirrors must all be in proper working order prior to the start of a trip. If any of these devices are not working or are damaged, they must be replaced prior to the start of the trip.
5. Wheels, rims, and emergency equipment (flares, reflective triangles, communication radio, and so on) must be inspected for damage and defects. Wheels and rims, if damaged, must be replaced, because they can cause loss of control and accidents. Emergency equipment must be carried and maintained on every commercial vehicle. The required number of flares, reflective triangles, and radios must be present, and they must be in proper working order and have working batteries. It is prudent to carry extra batteries. Emergency equipment may include extreme cold-weather clothing in case of a breakdown or being stranded.

During inspections, the cargo must be examined to be sure tie-downs or other securing methods have not become loose. The cargo must be thoroughly inspected for shifting that could cause a loss of cargo and possibly cause the truck to overturn on a curve. If cargo has shifted and the driver cannot correct the problem, the truck must be taken out of service until the load can be secured properly. When trailers are security sealed and the driver cannot inspect the cargo for shifting, unusual noises could indicate shifted cargo, and the driver should warn unloading personnel of a possible hazard as they open the trailer door.

Figure 25 is an example of an inspection record. It can be modified to accommodate different fleet vehicle types and other information needed. The author suggests that vehicle trip sheets be kept for approximately one year and reviewed to determine whether retraining is necessary.



DRIVER'S INSPECTION REPORT

MAINTENANCE (SEE INSTRUCTIONS ON REVERSE SIDE) CHECK DEFECTS ONLY. Explain under REMARKS X 6877605

COMPLETION OF THIS REPORT REQUIRED BY FEDERAL LAW, 49CFR 396.11 & 396.13.

Truck or Tractor No. ____ Mileage (No Tenths) ____ Trailer No. ____

Dolly No. ____ Trailer No. ____ Location ____

ATA/VMRS System Code Numbers for Shop Use Only ©1990 American Trucking Associations, Inc.

POWER UNIT

GENERAL CONDITION	IN-CAB	EXTERIOR
☐ 02 Cab/Doors/Windows	☐ 03 Gauges/Warning Indicators	☐ 34 Lights
☐ 02 Body/Doors	☐ 02 Windshield Wipers/Washers	☐ 34 Reflectors
☐ __ Oil Leak ____	☐ 54 Horn(s)	☐ 16 Suspension
☐ __ Grease Leak ____	☐ 01 Heater/Defroster	☐ 17 Tires
☐ 42 Coolant Leak	☐ 02 Mirrors	☐ 18 Wheels/Rims/Lugs
☐ 44 Fuel Leak	☐ 15 Steering	☐ 32 Battery
☐ __ Other ____ (IDENTIFY)	☐ 23 Clutch	☐ 43 Exhaust
	☐ 13 Service Brakes	☐ 13 Brakes
	☐ 13 Parking Brake	☐ 13 Air Lines
ENGINE COMPARTMENT	☐ 13 Emergency Brakes	☐ 34 Light Line
☐ 45 Oil Level	☐ 53 Triangles	☐ 49 Fifth Wheel
☐ 42 Coolant Level	☐ 53 Fire Extinguisher	☐ 49 Other Coupling
☐ __ Belts ____	☐ 53 Other Safety Equipment	☐ 71 Tie-Downs
☐ __ Other ____ (IDENTIFY)	☐ 34 Spare Fuses	☐ 14 Rear-End Protection
	☐ 02 Seat Belts	☐ __ Other ____ (IDENTIFY)
	☐ __ Other ____ (IDENTIFY)	

TOWED UNIT(S)

☐ 71 Body/Doors	☐ 16 Suspension	☐ 77 Landing Gear	☐ 79 Rear-End Protection
☐ 71 Tie-Downs	☐ 17 Tires	☐ 59 Kingpin/Upper Plate	☐ __ Other ____
☐ 34 Lights	☐ 18 Wheels/Rims/Lugs	☐ 59 Fifth-Wheel (Dolly)	☐ ____ (IDENTIFY)
☐ 34 Reflectors	☐ 13 Brakes	☐ 59 Other Coupling Devices	

REMARKS: ____

REPORTING DRIVER: Date ____ Name ____ Emp. No. ____

REVIEWING DRIVER: Date ____ Name ____ Emp. No. ____

MAINTENANCE ACTION: Date ____ Repairs Made ☐ No Repairs Needed ☐ R.O. #'s ____ Certified By: ____ Location: ____

SHOP REMARKS ____

Reorder ATA form # C0830 from: American Trucking Associations, 2200 Mill Road, Alexandria, VA 22314-4677 1 800 ATA-LINE

FIGURE 25. **Example of an inspection record**
(*Source:* ATA 1996, 19-1–19-12)

Driver Distraction

The specific sources of distraction among distracted drivers are listed in Table 13.

TABLE 13

Specific Driver Distractions

Specific Distraction	% of Drivers
Outside person, object, or event	29.4
Adjusting radio, cassette, CD	11.4
Other occupant in vehicle	10.9
Moving object in vehicle	4.3
Other device/object brought into vehicle	2.9
Adjusting vehicle/climate controls	2.8
Eating or drinking	1.7
Using/dialing cell phone	1.5
Smoking related	0.9
Other distrction	25.6
Unknown distraction	8.6
	100.0

(AAA Foundation 2001)

Percentages for the different types of distractions should be viewed as preliminary estimates that are likely biased by differential underreporting. These are research results that will be useful in building a broader understanding of driver distraction. The percentages for the different types of distractions should not be used to guide policy development.

Young drivers (under 20 years of age) were most likely to be involved in distraction-related crashes. In addition, certain types of distractions were more prominent in certain age groups: adjusting the radio, CD, or MP3 player among the under 20-year-olds; other occupants (e.g., young children) among 20–29 year-olds; and outside objects and events, among those age 65 and older. Variations by the gender of the driver were less pronounced, although males were slightly more likely than females to be categorized as distracted at the time of their crash (AA Foundation 2001).

Drivers see more poorly at night, and pedestrians overestimate how visible they are to motorists, according to Richard Tyrell, a Clemson University psychology professor and researcher who has been studying night driving for 20 years. Tyrrell has conducted more than 30 experiments to find ways to keep both drivers and pedestrians safer after dark (Tyrrell et al. 2009).

Over the weekend, two pedestrians in Aiken County died after being hit by cars while trying to cross a highway at night, and a Walhalla man died after he was struck by a Greenville County sheriff deputy's car while crossing a street early in the morning.

Each year about 5000 pedestrians are hit and killed in traffic accidents. "Most of those incidents happen at night even though there are fewer drivers," Tyrrell said. Tyrrell's research has found that drivers steer pretty well at night, which may lead to not slowing down. Most drivers also rely too heavily on low-beam headlights (Tyrrell 2006).

Most pedestrians wear dark clothing, making them harder to see and when they do wear reflective material, it usually consists of a vest. Reflective material would be better if people wore it on their joints so it would move more. "Humans are good at seeing humans in motion" (Tyrell 2006).

Tyrrell and another Clemson psychology professor, Johnell Brooks, use a driving simulator to study how drivers of different ages perform at night. They have found that while drivers stay in their lanes well, they overestimate how well they see in the dark. Older drivers have more difficulty seeing at night but then also tend to be more aware of the problem. The simulator allows researchers to put people into what might be dangerous situations and record how they react (Balk et al. 2008).

In another experiment, a volunteer pedestrian walks in place in a low-traffic area in a Clemson neighborhood. Sometimes the volunteer wears only dark clothing, other times reflective material. Student volunteers then are driven through the area and push a button when they first see the pedestrian. The study found that if people are going to wear reflective material, the best place is on the ankles because they move as you walk and the low beams will shine on the ankles first. Tyrrell said people need to be educated about the hazards of night driving and hopes pedestrians will wear more reflective clothing and stay away from busy traffic areas. If such warnings "can get into their heads before they decide to step into an intersection, I've succeeded," he said (Balk et al. 2008).

Driver Training

Driver training begins with a driver's application for a commercial driver's license and should never stop. The interviewing, hiring, and training of transit bus drivers in particular should be taken very seriously, since dozens of passengers will be exposed to unsafe situations if the bus driver is not properly evaluated and trained. Even when drivers have commercial driver's licenses (CDLs), a safety-conscious transportation organization will continually provide them with updated training and critique their driving records. At the time drivers are being considered for hiring, transit companies should order a motor-vehicle driving license abstract to determine whether any moving violations appear on their record. With constant monitoring and continuing driver education, insurance carriers may reduce premiums if companies demonstrate a serious commitment to employing safe drivers and maintaining driving safety. If fleet operators are not able to teach defensive driving in-house, there are trucking associations [such as the American Trucking Association (ATA) and regional or state trucking associations] that offer defensive driving courses. Drivers should be instructed about stopping distances and following distances and participate in emergency warning-device exercises. Transit companies should have written policies on conducting accident analyses and thoroughly review accidents to determine whether they were unavoidable or avoidable. This type of analysis can help to determine whether drivers need refresher courses.

During driver training, issues relating to vehicle size should be discussed thoroughly, including methods of performing emergency maneuvers. Safe driving requires qualified drivers, and professional drivers should have as their objectives the desire and pride to improve professional driving knowledge and awareness, good driving judgment, foresight, and skill. Driver training must encompass pretrip inspections, fatigue and stress, handling emotions, and having a good attitude, as well as the effects of age on a driver's vision, hearing, and mobility. Driver retraining is a good time to spot bad habits and correct them. People who drive more than one type of vehicle must also be instructed on the unusual aspects of safe operation for each type of vehicle they will be expected to operate.

Buses must be driven with a high degree of safety because they carry a very precious commodity: human passengers. Specific considerations must be incorporated into the decisions bus drivers make regarding where to stop buses in relation to parked vehicles, high curbs, pedestrian hazards, crosswalks, and so on. Safely picking up passengers is also crucial, since passengers boarding buses can be seriously injured. Bus drivers should be instructed that they are authorized to pick up and drop off passengers only at designated bus stops.

Bus drivers must constantly evaluate their surroundings. They must be sure the bus is safe to operate in the existing environment given the bus's width, length, and height. They must be sure there are no overhead hazards that can hit the top of the bus and jolt the occupants. One way to prevent this type of incident is for drivers to know the height of the bus. Choosing appropriate locations for bus stops is extremely important and is usually done by transit companies in cooperation with local towns and law enforcement. Locations have good points and bad points and must be evaluated in total context for the good of the overall ridership.

Accident Avoidance and Anticipation

The motor fleet industry must consider and create a system to control accidents and injuries. The core aspects of an efficient system include record keeping, analysis, prevention activities, and evaluation. Records that reveal what types of accidents typically occur must be kept so that avoiding them can become part of a teaching program. Records also indicate injuries sustained by employees and can be a means to analyze the cost of injuries to the fleet company. A simple accident register can be prepared using the Department of Transportation (DOT) Federal Highway Administration (FHWA) requirements in 49 CFR Part 390.15. This information can be found online at the U.S. Department of Transportation's Web site (www.dot.gov). Two important aspects of accident analysis are specifics of the cause of the accident and recommendations for what can be done to eliminate the same type of accident in the future. An accident review should include the following data (ATA 1996, 56–59):

- the ***employee's name*** (Repeated problems involving the same individual will come to the surface, and appropriate action can be taken.)
- the ***time of day, lighting conditions, and other conditions*** that may or may not have contributed to the accident.
- the ***day of the week*** (Patterns may emerge that indicate solutions. For example, if records show that accidents occur more frequently on the first and last day of the week, this could be an indication of preoccupation by employees.)
- ***hours driver had been on duty at the time of the accident*** (This information must be recorded by regulation, but can also be critical in evaluating driver fatigue.)
- ***weather and road conditions*** (They can indicate the conditions that most often cause accidents, and steps can be taken to work around them.)
- the ***type of vehicle***, including handling characteristics and whether the vehicle was being loaded or unloaded
- the ***speed and condition of the vehicle*** (These are usually looked at first as primary accident causes.)
- the ***type of accident*** (For example, if the driver's back was turned when the accident occurred, this may indicate that the driver needs additional training.)
- ***what the employee was doing at the moment of injury, body part(s) injured, and other pertinent information that will help to analyze the accident***

Accident avoidance and anticipation are major factors in safe driving. Avoiding an accident requires anticipation and the proper choice of an evasive action. In order to anticipate a possible hazard in the roadway ahead, the driver must be attentive—not distracted. Accident avoidance is a learned process—not an inborn one. For example, many drivers, when confronted with a vehicle entering their travel path from the right, steer to the left in an effort to avoid impact. If, under these circumstances, the driver steers to the right, the encroaching vehicle will usually pass through the driver's original travel path and an impact will be avoided. This is a quick response that can be learned.

Anticipation requires more than attention; it requires training and a conscious desire to understand what constitutes a developing hazard. A hazard could develop when another vehicle slows to a stop from either the left or right or when traffic ahead becomes congested. Drivers should always enter intersections with their foot off the accelerator and hovering over the brake so that their reaction time is cut to a minimum. An accident has been said to be an unfortunate event resulting from unavoidable causes. While some may think this definition is true, others question the term *unavoidable*. Accidents can be unfortunate, but they should never be accepted as the cost of doing business. Many can be avoided, depending upon the circumstances and the drivers involved. A term used by many, *preventable collision*, is defined as a collision in which the driver failed to do every reasonable thing. While litigators may latch onto this terminology, there is much more to the term preventable. Drivers should be aware of some preventable causes of collisions:

- slowing down too late
- failing to scan the road
- failing to check blind spots
- not driving at the appropriate speed given an adverse condition, regardless of the posted speed limit
- following too closely
- not focusing on the driving task

Other factors contribute to accidents, such as the condition of the roadway, work-zone traffic, and heavy vehicle loads. Factors can generally be categorized into three areas: driver factors, vehicle factors, and condition factors. Avoiding accidents requires training in recognizing hazards, understanding proper defensive maneuvers, and deciding and acting correctly in time to prevent an impact. One anticipation training tip is for drivers to ask themselves "What if?" To plan ahead, drivers can be driving down a roadway, looking for an escape route. A constant "what if" strategy can help drivers predetermine accurate evasive maneuvers when faced with specific hazards.

Turning and Maneuvering

Drivers of large trucks must use extreme care when turning and maneuvering. The large mass and length of commercial and fleet vehicles demand vigilance and caution that is referred to as managing space—in other words, operating, parking, and maneuvering fleet vehicles. If drivers are not thoroughly familiar with the space and rear vision limitations of the vehicles they operate, they will be at a disadvantage and may become involved in avoidable incidents. Understanding the length and turning ability of large vehicles is crucial when learning how to drive them. Space is limited on highways and must be preserved during parking and limited-space maneuvering. Braking maneuvers require drivers to be familiar with the weight of their vehicles, their cargo, and the distance needed to safely brake and come to a complete stop. Drivers also must be aware of the spacing between their vehicle and the one in front of them—the *following distance*. This is a crucial factor in avoiding rear-impact accidents. Some transportation engineers the author has spoken with understand and acknowledge that roadways in the United States are built and designed mainly for passenger vehicles, not for fleet or commercial vehicles. Lanes are normally eleven to twelve feet wide. Although curves are designed for speeds greater than the posted speed limit, drivers of commercial trucks must be aware of design limitations and know that speed limits on curves should not be exceeded.

Overhead space is another factor drivers must consider when operating large vehicles in close spaces or on open roadways. Overpasses are generally fourteen feet high. It is important for drivers of closed-end trailers to know their trailer's height and for drivers of flatbed trailers to know the height to the top of their cargo in relation to the height of each overpass they drive under (ATA 1996, 85-87) so that overpass collisions can be avoided. Drivers must also be aware that strong winds can force trailers out of travel lanes and that vehicles could hit overpass abutments or other vehicles passing in adjacent lanes.

Making right turns in urban areas may be very difficult since vehicles in the right lane of the intersection may not give trucks sufficient turning space. Signaling long before starting the turn is crucial. Attempts to squeeze by in limited roadway spaces, especially in city driving, can cause impacts with other vehicles and pedestrians. To make a proper turn, a driver must keep the vehicle in its own lane and make a wide turn into the two lanes of the street he or she is turning onto (NJDOT 1988, 2-22–2-25). All turns must be approached with caution. Before starting a left turn, drivers should keep the vehicle in the center of the intersection and not cut the corner.

When backing into a dock, drivers must be prepared to use a spotter. Sometimes—usually at loading or unloading docks, not on roadways—the trailer will be parked and the tractor will be in a jackknifed position.

Tanker trucks and their cargo are constantly moving during transit. Tanker trucks are designed with a baffle system that slows displacement of the liquids in the tank compartment. These trucks are especially susceptible to rollover since the baffles are sometimes lateral and liquids shift to the outside during a turn. The suspension of tanker trucks is usually stiffer than that of other trucks to allow for very little compression during turns so that liquid cargo remains stable.

Ergonomic and Injury Biomechanical Issues

Investigating Employee Injuries

The musculoskeletal system is quite complicated and is very vulnerable at times. The *musculoskeletal system* includes tendons, ligaments, fascia, cartilage, bone, and muscle. Soft-tissue injuries usually relate to tendons, ligaments, fascia, and muscle. Soft-tissue injuries can occur in an occupational environment as well as a nonoccupational environment, such as motor-vehicle impact and so on. Functional units or joints are a necessary connecting point that allows linear body segments to move and interact.

Ligaments connect bone to bones, which provide stability through the joints, and tendons attach muscle to bone, which transmits force. The *fascia* is also a connective tissue that covers organs or parts of organs and keeps them separate within the body cavity. The fibers run parallel in tendons, nonparallel in ligaments, and irregularly in the skin. Each group of fibers creates strength of its own, which is based upon the structure of the fibers. Collagen fibers, while under tension, first stretch slightly and then become stiffer until failure. The fibers have a wavy pattern, which accounts for the initial slight stretching until the wavy pattern is eliminated. Elastic fibers are weakened and become brittle as they stretch greater than collagen fibers and can deform more than at higher degrees. As the elastic fibers stretch, they reach a point where they stiffen, and failure occurs with little warning. Connective tissue as one conceding gets its strength, depending upon the number of collagen or elastic fibers contained in the tissue.

Bone can be molded or change in size and shape based upon the stress and the duration of the stress. The relationship between change and stress is still unknown but could be described mathematically. The skeletal system reaches its maximum mass (strength) at about age 30, after which bone loss occurs continuously. Gradual aging changes normal bone into osteoporotic bone at an accelerating rate. In the early 30s, there is little change in bone loss between men and women, but it sharply increases for women after menopause. Changes relating to aging produce the following results:

- continuing decrease in mineral content
- cortical bone becomes thinner
- increasing diameter of long bones, which increase the moment arm
- decreasing trabeculae (inner core of cancellous bone) in cancellous bone

For these reasons, the bones are weaker and fracture more often after trivial trauma in older people, especially women.

Disc compression studies have shown the discs are flexible at low loads and resistance increases at higher loads (Backaitis 1993a). This study also indicates the discs are particularly at risk from lateral bending and rotation, and portion is especially harmful to the disc and responsible for failure when combined with compression. Compressive loads to the lumbar-supplied failure occur in the end plates, then in the vertebrae bodies and, lastly, in the discs proper. There is great variation among individuals and age groups in equating moment rotation and force deformation of the motion disc segments.

Muscle strength is of great importance, since many jobs in industry require workers to exceed their strength or at least approach their limit. Muscular strength is defined as the strength muscles can produce during maximum exertion. *Muscular strength* is separate from *muscular endurance*. The latter is a measurement of the amount of muscular strength over time intervals. Naturally, the initial exertion of muscular strength is greater for a short time but, over a longer time, the measured muscular strength is reduced. This correlation is important when creating jobs requiring muscular strength over a worker's shift. *Isokinetic strength* is determined by controlling the movement of the joints. *Isotonic strength* requires continuing muscle activity while the velocity of the muscle changes. *Static strength* involves fixed postures (holding an object) and is usually associated with isometric contractions or exercises. Isokinetic, isotonic, and isoinertial are considered dynamic muscular movement, such as lifting or pushing. Strength and force curves can be developed and analyzed upon obtaining data from subjects. This information is valuable for matching the worker with the required task.

Sitting while performing tasks saves energy and is generally best for close and precise work. The lumbar curve is *lordotic* (backward curve), since the vertebrae and discs are thicker in front than in the back. This is the posture that creates the upright torso, which is what all of our mothers meant when they said "sit up straight." The lumbar spine articulates, or moves, while the sacrum is fused with the pelvis. This feature creates a rotation about the pelvis and shapes the lumbar spine. In a sitting posture, the pelvis rotates forward, which creates lordosis in the lumbar. When a person is sitting in a relaxed posture, the lumbar may be either straight or in a slight *kyphosis* (forward curve) position. The spine is comprised of four segments: (1) the cervical with seven vertebrae; (2) the thoracic, with twelve vertebrae; (3) the lumbar, with five vertebrae; and (4) the sacrum, also with five vertebrae that are not articulated. The posture shape of a seatback can influence the curvature of the spine. Normally, the cervical is in slight lordosis, along with the lumbar, and the thoracic is in slight kyphosis when a person is standing.

There are times when an injury claimed by an employee is investigated; either in response to a workers' compensation claim or civil or criminal litigation. The claimed injury can occur while driving a fleet truck or fleet passenger vehicle. Your attorney will usually take the lead in this scenario but you will still be expected to assist in the claim defense and process.

Injury biomechanics includes the analysis, research, and calculations relating to a specific accident (motor vehicle, slip, trip, fall, etc.). The conclusion of injury biomechanics is to determine from the evidence if there exists a mechanism of injury to support the claim. The mechanism is crucial in determining the probability of injury. Biomechanics does not conclude an injury could or could not have occurred, only that a mechanism is present or not. Studies are used to quantify forces of an impact of an accident to help evaluate the probability of the claimed injury. The accuracy of the injury biomechanical analysis is directly dependant on the evidence, testimony, and available replicate research.

Injuries to employees may include upper and lower extremities, neck, back, and so on. All claimed injuries have a mechanism of injury and must be accurately analyzed using the appropriate scientific principals (Rivers 2001, 53–57).

Occupants in vehicles are subject to injuries and fatalities if safety is not of prime importance, and of course, occupants must actually use seatbelts in order for them to prevent injury or death. It is easy to understand that, in a collision between a large commercial truck and a typical passenger vehicle, the truck occupants will probably be injured less seriously than those in the passenger vehicle.

Seatbelts use two types of mechanical systems: (1) *gravity* or (2) a *pretensioner*. In the gravity-operated seatbelt, a mechanism in the spooling portion simply rotates upon emergency braking. When the front of the vehicle dips, the mechanism locks the seatbelt in place. The disadvantage of this type of seatbelt is that unless the occupant has the seatbelt properly positioned and tight against his or her body, the slack in the seatbelt remains on impact. The pretensioner system resolves this problem: the pretensioner automatically takes up the slack and usually presses the occupant against the back of the seat.

Occupant protection in motor fleet and commercial vehicles is usually more of a concern with passenger vehicle fleets or small vans than with large tractor-trailers. Usually during impacts, drivers of tractor-trailers or large trucks do not sustain serious injury due to the large mass of the vehicle. If the vehicle rolls over, however, drivers of such vehicles could be severely injured or killed if they did not use a seatbelt.

While today it may be difficult to believe, until the 1950s seatbelts were not even considered an option on most vehicles, apparently because the public was not demanding safety items on vehicles they purchased. Research into the safety of seatbelts was not widely understood or demanded. However, occupant protection in standard passenger vehicles requires understanding and proper use of seatbelts. seatbelts should be adjusted so that the shoulder portion passes between the middle of the shoulder and the neck. The belt must be snug so that the wearer cannot move forward or side to side upon impact. Figure 26 is a diagram of a side view of a typical seat-belt locking mechanism without a pretensioner. Diagram B-2 is the position of the locking mechanism upon impact. If occupants move out of position during an impact while an

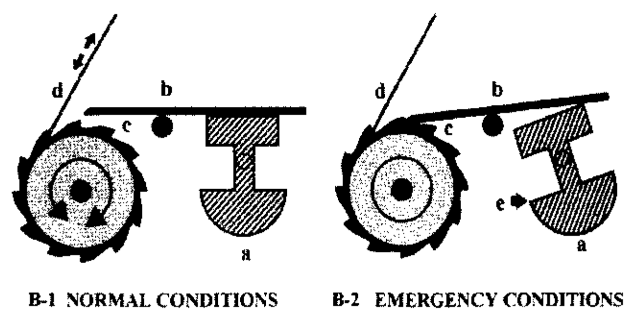


FIGURE 26. Side view of a typical seatbelt locking mechanism without a pretensioner (*Source:* Rivers 2001, 53–57)

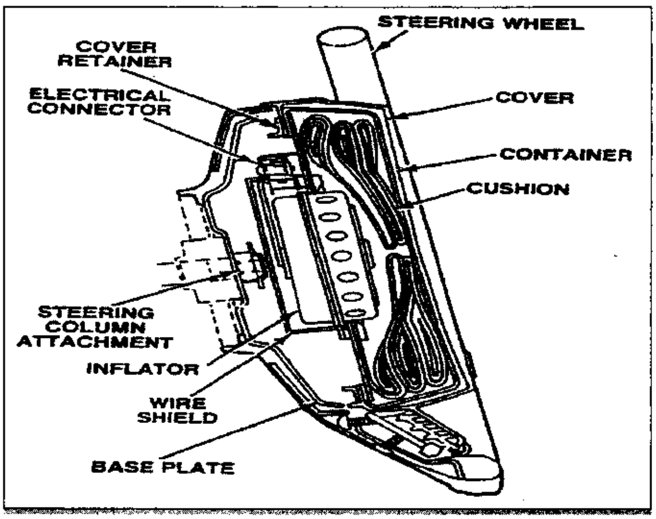


FIGURE 27. A cutaway showing the manner in which an airbag is folded inside the steering wheel (*Source:* Rivers 2000, 55–60)

airbag deploys, more severe injuries could occur. Figure 27 shows a folded airbag ready to be deployed.

One of the most prevalent types of injury in motor-vehicle impacts is the whiplash (cervical spine) injury, which is a severe problem in the United States. Even though most people survive this type of injury, the cost from lost work and medical treatment is a burden on the U.S. economy and on productivity. Accurate prediction of this type of injury is crucial if prevention devices are to be invented and proper medical diagnosis and treatment is to be effective through the understanding of the mechanisms of the injury.

Statistics concerning whiplash (Croft 1995, 86–98) include:

- Most injuries occur at crash speeds below 12 mph.
- Most cars withstand 8–12-mph impacts without vehicle damage.

- More than half of all low-speed, rear-impact collision (LOSRIC) injuries occur without vehicle damage.
- There is no correlation between vehicle damage and injury outcome.
- During impact, the peak acceleration of the occupant's head is much greater than the peak acceleration of the vehicle.
- In a 5-mph crash the occupant's head typically experiences 10–12 g of acceleration.
- More than three million Americans sustain whiplash injuries every year.
- The reported risk (probability) of injury in a LOSRIC is 35 percent to 68 percent. The Japanese Auto Insurance Rating Association reports a 50 percent risk of injury.
- About 10 percent of those injured become permanently disabled.
- *Minor* neck injuries account for up to 60 percent of all permanent impairment claims.
- For every 6 million occupants in LOSRICs,
  - about three million will be injured (approximately the population size of South Carolina)
  - about 1.5 million will have chronic pain (approximately the population size of Nebraska)
  - about 400,000 of those with chronic pain will become disabled, usually due to pain (approximately the population size of Wyoming) (Microsoft Encarta 2006).
- Nearly half of all chronic neck pain in America is due to car crashes—mostly LOSRICs.
- About 9 percent of all Americans suffer from chronic neck pain due to LOSRICs.
- Children are two to three times more likely to suffer whiplash injuries than adults.

A conservative estimate of the cost of spinal cord injuries to the health and insurance industries due to medical costs and lost productivity is $97 million annually (Nahum 2002, 324–330).

The number of spinal cord injuries, including whiplash, in the United States continues to climb and is a major concern of the automobile, insurance, and health industries as evidenced by the following data (Shands 1993, 75–79):

- The number of new injuries in the United States in 2007 was about 10,000.
- The gender breakdown for whiplash is 82 percent male, 18 percent female.
- The highest per-capita rate of injury occurs between the ages of 16 and 30.
- The leading causes of spinal cord injury are
  - motor-vehicle accidents: 44 percent
  - acts of violence: 24 percent
  - falls: 22 percent
  - sports: 8 percent (two-thirds from diving)
  - other: 2 percent.

Whiplash analysis does not seem to be consistently accurate, and the true mechanisms are still not fully understood. The mechanisms and their predictability must be thoroughly understood by the medical community and automobile manufacturers in order for proper treatment to be given and prevention methods instituted. See "Important Terms" at the end of this chapter for definitions of biomechanical injury anatomy terms.

As previously noted, the mechanisms that cause whiplash are not fully understood. Kornhauser of EM Systems Inc., concluded "it is apparent that the injury threshold, the approximate level of trauma to cause injury, is above 8 kph, or 5 mph, *even for subjects with mild preexisting spinal degeneration*" [author's emphasis] (Kornhauser 1993, 1–14). Further uncertainty is evidenced by Nielsen, et al., who tried to accurately predict the human response to delta-v (severity of impact) using mathematical modeling. They concluded "further work is required to explore the validity of the model used to calculate delta-v" (Nielsen et al. 1997, 23–28). Delta-v is a widely used measurement for determining the probability of injury. It is a measurement of the change of velocity over time. For example, decelerating from 50 mph to 0 mph in 0.1 second is more severe than decelerating from 50 mph to 0 mph in 0.5 second. The probability of injury depends on both the change of force and the amount of time over which the change of force takes place. Astronauts, for example, are not injured when accelerating from zero to approximately 18,000 mph because of the length of time it takes for this change to occur. It is the opinion of the author that, while the mechanisms of whiplash injury are controversial and not totally understood, diagnosis of whiplash without a full understanding of the mechanisms involved is often given.

Whiplash injury has a great potential for insurance fraud and can greatly increase the cost of insurance for all consumers. This problem is worldwide, as evidenced by Cupid's research, which concluded that "there is urgent need to introduce accident reconstruction in the Caribbean [to counter insurance fraud]. Insurance companies continue to receive a level of practice that needs to be brought up to international standards" (Cupid 2002, 1–16). The research associated with this type of problem is of paramount importance. Millions of dollars in healthcare and insurance costs could be saved and devoted to designing better and more efficient safety equipment to reduce the problem and costs. The United States is not the only country with widespread insurance fraud, and we may be able to learn from other countries how to prevent or at least greatly reduce insurance fraud.

Pintar states a need for "further research to better understand the biomechanics and mechanisms of [motor-vehicle injuries]" (Cupid 2002, 1–26). Learning how to accurately and reliably diagnose whiplash and understanding the mechanisms that cause it, can aid in the fight against insurance fraud. The research of Lawrence et al. concluded that "it is not known if the conclusions drawn from [research] testing can be applied to higher severity collisions" (Kornhauser 2002, 1–15).

It is the opinion of the author that future studies should focus on determining how to accurately predict the occurrence of whiplash injuries, beginning with a review of present research in assessing whiplash probability. In order to fight whiplash fraud, determining injury thresholds for the general population is critical. Fraud from rear-end motor-vehicle accidents, according to insurance advertising, has increased dramatically over the past few years. Research can assist in preventing fraud by developing a more accurate understanding of the mechanism of injury and the probability of injury.

Driver Work Space and Vision

The interior of a truck's cab can be considered a closed environment, and as such must be controlled for the driver's comfort. Air temperature, temperature of surrounding surfaces, humidity, air movement or ventilation, and air quality must all be controlled. The temperature of the human body is not a constant 98.6°F throughout. This temperature, also known as *core temperature*, is found only in the interior of the brain and other organs. There is great temperature variation in the muscles, the limbs, and the skin—called the *shell temperature*. The body automatically attempts to regulate body heat by either conserving or dissipating it. The rule of thermodynamics states that energy always flows from a warm location to a cold location. As a driver's body begins to suffer from excessive heat or cold, his or her safety and the safety of passengers and other motorists becomes jeopardized (Kroemer 1999, 355–369).

The temperature of adjacent surfaces within a truck's cab should not fluctuate more than two to three degrees. Humidity does not affect temperature substantially, but air begins to feel stuffy within the range of 80 percent humidity at 18°C (64.4°F) and 60 percent humidity at 24°C (75.2°F). Conditions also become unpleasant when air movement is below 0.5 meters per second (m/s), even when the air is warm. Air currents from behind are more unpleasant than frontal currents, and the neck and feet are especially sensitive to drafts; a cool draft is less welcome than a warm one. Seat occupants have reported finding air movement unpleasant at more than 0.2 m/s. Recommended temperatures for comfort are 20–21°C in the winter and 20–24°C in the summer for sedentary work such as driving (Kroemer 1999, 370–377).

The driver's environment is important for both comfort and safety. The ergonomics of the various dials and switches contributes to driver comfort by reducing fatigue and to driver safety by reducing unnecessary movement or distraction. When drivers take over-the-road trips in large trucks with large trailers, sleeping accommodations must be considered as well as aspects of driver comfort in all climates. It is also important to consider ease and safety of entering and exiting the cab. The number and placement of footholds and handholds and the distance between each pair are important because some tractors are high enough above the ground that a slip could cause a serious injury (Woodson 1992, 82-85).

Driver limitations must be considered during interviewing for, hiring for, and operation of motor-vehicle fleets. The ability of operators to drive in inclement weather should be strongly analyzed since they will be expected to drive in all types of environments and with different types of cargo. Important assets for professional truck drivers are good judgment and not taking chances. Drivers limit themselves by using poor safety practices and having avoidable accidents. Vision is one of the most important factors of safety since it is mandatory for the safe operation of fleet vehicles. Poor visibility, whether due to poor roadway design, weather, an obstructed windshield, or a poor driving position, must be dealt with immediately.

Limitations placed upon drivers also come from the type of truck being driven and the cargo being carried. If the truck is a tractor with two trailers, it will be more difficult to drive and have more limitations than a tractor with one trailer. Drivers must understand, realize, and consider these limitations when making maneuvers.

Visibility, both front and rear, is important, since without good, clear visibility the operation of fleet vehicles is extremely compromised. Visibility is directly affected by seating placement and window size and shape. Visibility is also affected by the placement of dashboard dials and switches; if they are placed incorrectly, viewing them could take the driver out of safe visibility range for operating the vehicle. If the numbers on the dials are too small or the lighting within the dials is too dim, the driver will have difficulty instantly determining the position of the hands. Dials should be placed so that they are not partially or totally blocked by the steering wheel or another fixed object in the tractor's cab. Dials should be designed and installed so that drivers do not have to move their head or torso to read them. Drivers should also be able to read any dial on the dashboard without staring or removing their eyes from the roadway for an unsafe period of time, usually more than one second. Visibility to the back of the trailer must be unrestricted, because the cargo may become loose and the driver must stop when he sees that the cargo needs to be tightened.

The interior of the tractor must be an ergonomically friendly environment, since over-the-road or other long trips can easily fatigue drivers and create unsafe situations. Special attention should be paid to temperature, ventilation, noise, and vibration. Over time, vibration—the oscillating motion of the body and its limbs and organs—will cause fatigue and produce an unsafe driving situation. *Free vibration* is caused by internal forces, and *forced vibration* is caused by external forces. Truck drivers are constantly subjected to vibration forces since they sit on a relatively stiff seat in a vehicle with a relatively stiff suspension. Harmful vibration usually occurs at the lower end of the vibration frequency scale (Chaffin 1999, 463–473).

The vibration and frequency of noise is harmful to the human ear. Humans are sensitive to vibration of the *vestibular* (hearing) system at low frequencies—1 to 2 hertz (Hz), such as vibrations generated by ships, cranes, or aircraft. Humans are also sensitive to vibration of the body at frequencies of 2 to 20–30 Hz, the middle frequency range, which is generated by vehicles and aircraft. At high frequencies—greater than 20 Hz, the receptors in muscles, tendons, and skin are highly sensitive. This high-frequency vibration is generated by tools or machines (Chaffin 1999, 485–488).

Designing driver and passenger spaces in buses requires special consideration. Drivers must be able to see nearby hazards or objects as well as necessary gauges and dials. They must also be able to see onboard passengers in case one falls or needs assistance. Seeing passengers is very important during the operation of the bus as well as during stopping and starting. Boarding passengers must also be visible to drivers since injuries can occur when drivers prematurely close access doors or pull away when all passengers are not properly seated.

Material Handling

Commercial fleet operators must be concerned with material-handling injuries when loading and unloading their vehicles. Forklifts, cranes, and hoists are used regularly at truck depots, and rules for operating these types of equipment can be found in OSHA regulations 29 CFR parts 1910.179 and 1926.550. Any time large machines are used, space is at a premium. Minimum width of warehouse aisles is 36 inches when small hand trucks are used and 10 feet if forklifts are used (Marshall 2000, 372–375). NIOSH offers the following statistics:

- Over 60 percent of lower back pain is caused from overexertion.
- Overexertion injuries of the lower back account for a significant loss of work time, and less than one-third of injured employees return to work.
- Overexertion injuries account for one-fourth of all reported occupational injuries in the United States, with some industries reporting that over 50 percent of their total injuries are due to overexertion.

Many characteristics of containers affect material-handling systems, including the load dimensions, distribution of the load, handling the load, and stability of the load. There are physiological limits to lifting based upon size and weight of the load and the frequency of lifting. The more often a load is lifted, the less weight a worker can safely handle. People who lift should consider the following NIOSH recommendations (Marshall 2000, 376–386):

- Lifting should be smooth, with no sudden acceleration.
- Objects lifted should be of moderate width—less than approximately 75 centimeters.
- The lifting path should be unrestricted, with no need to brace the torso with a hand.
- Handles should be secure and in good shape, and temperatures should be favorable to lifting (not too cold or too hot).

NIOSH uses the following formula to determine the recommended weight limit (RWL) for lifting:

$$\text{RWL} = LC \times HM \times VM \times DM \times AM \times FM \times CM \quad (8)$$

where

LC = the load constant,

HM = the horizontal multiplier,

VM = the vertical multiplier,

DM = the distance multiplier,

AM = the asymmetric multiplier,

FM = the frequency multiplier, and

CM = the coupling multiplier

These values can be obtained from D. Chaffin's *Occupational Biomechanics* (1999, 315–324).

When material handling is done with equipment such as a forklift or lift truck, the forklift/lift truck operators must be trained, and if they are involved in an accident or near-miss, they must be retrained. Forklift operators must pay special attention to moving in and out of open trailers from a dock since there may not be a smooth transition between the two and there may be a gap that could cause an accident. Usually a large metal sheet is placed over the gap for safety. Forklift operators must also never go around corners without sounding the horn to alert possible pedestrians (NSC 1999, 22–25).

A maintenance schedule must be kept so that fleet vehicle maintenance is performed regularly. If items need to be replaced, they should be replaced promptly even if they are approaching the end of their useful life. If safety items are not replaced but allowed to be used beyond their useful life expectancy, they could fail and cause an accident. Fleet vehicles should be equipped with all necessary parts and equipment that will assist drivers to safely reach a location for permanent repairs.

Loading and unloading should be done in a safe and efficient manner. The shifting of cargo on an open trailer is easy to spot, but on a closed trailer the cargo may shift without the driver knowing it. On a closed trailer, if the cargo has shifted it may fall when the trailer doors are opened, or the cargo may have been jostled to the point that it is unsafe to begin removing packages or boxes for fear that the rest of the cargo will fall. Loading is not only labor-intensive and time-consuming, but is also an art and must be thoroughly thought through prior to the start of the loading process. When cargo is organized by stops, it is convenient for the driver to check it for possible shifting prior to leaving each stop.

Determining the proper method for performing tasks requires planning and forethought. A preferred method, standard practice, and a time standard should be considered when attempting any job function. Training the worker is of utmost importance, since the worker must not only be trained in what the job function is but also how to safely complete the daily tasks. Several methods must be used to determine the safest way to perform a task, which include using accepted practice and safety scientific data for the subject task at hand. During the interview for the job position, the best worker in relation to experience, knowledge, safety, and physical criteria should be selected. A spirit of cooperation between management and the worker must exist so that the worker does not feel safety is only his responsibility or that management does not care about injuries. It has been clearly shown that a low number of injuries usually provide a higher profit. Another aspect of safety is dividing the workload as equally as possible, so that one worker does not have to perform his task faster and, consequently, in a less safe manner.

Biomechanical safety begins with knowledge of unsafe stress factors, which should be identified by the worker along with his or her supervisor. Trained persons who either perform the task or supervise the task performance can easily identify these stress factors. To analyze safe performance of tasks, one must be able to separate and evaluate each movement of a particular task. Each task has a minimum, median, and maximum time limit for performing the task safely. The evaluation of the worker and the subject task is required to set safe time limits for a particular job function. This motion can be predetermined for a specific task. Some of the movements include reach, position for most efficient movement, the release factor after the motion is completed, rebound as when pulling pieces apart on an assembly line, grasping or controlling an object, eye movement and focus, turning or manipulation of tools as parts, body segment motion, and motion of all or some of these movements simultaneously.

During lifting, the load should be kept as close to the body, lumbar spine, as possible, which results in a much smaller moment arm than if the weight was held outward. Figure 28 demonstrates the compression on the male back at various stages of the distance that the horizontal load (constant 650 kg) is from the spine at L5/S1. The spine must be supported by its own structure, along with the specific muscles; if it is not, it becomes unstable and can buckle under a very low compression force of

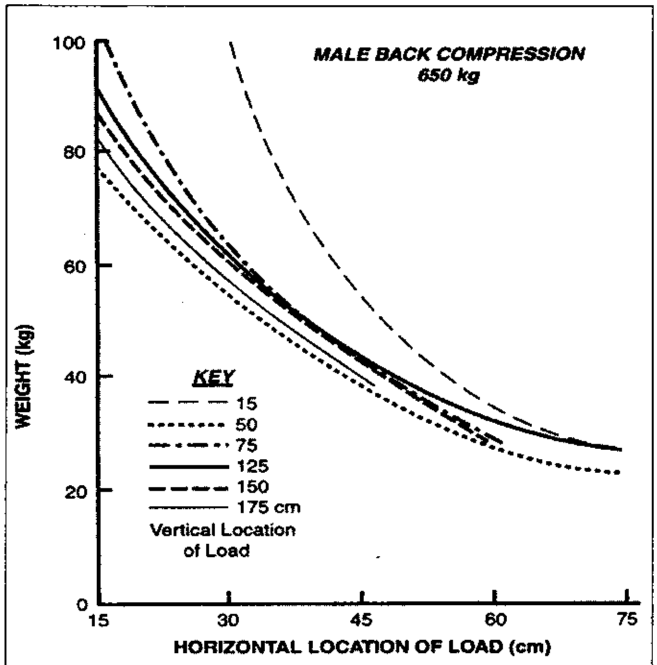


FIGURE 28. Male back compression in relation to the distance of a horizontal load from the spine at L5/S1 (*Source:* Chaffin et al. 1999)

approximately 20 newtons. The individual muscles exert lateral or front to back forces on the spine to prevent injury from bending and compression buckling. Loading on the disc is less during pushing than pulling, which is why material handlers are usually told to push instead of pull. Minimizing internal disc pressure can be achieved by having the backrest recline at approximately 120 degrees, and the lumbar support at approximately 5 cm. The greatest disc pressure was observed when the backrest was at 90 degrees with no lumbar support. Lumbar support affected lordosis, or backward banding, when the angle of the backrest affected disc loads (Andrews 2005).

There are a number of techniques for lifting. Many are described in other literature; the following are some of the more common techniques (Andrews 2005):

- Select strong people, based on testing, for heavy lifting.
- Bend the knees when in a squat in position, leaving the back straight.
- Do not slip, jerk, or twist during the strongest part while lifting.
- Use machines when possible.
- Divide the weight into smaller, more manageable parts.
- Use a good grip rather than a less secure one.
- If the load consists of smaller pieces, find a container, which will place the load in a more compact state, making sure that the weight is not excessive.
- Keep the load close to the body, since that will greatly reduced the moment arm and reduce the force on the spine.
- If possible, work at knuckle height; avoid lifting loads below the knees and above the shoulders.

Vehicle Design and Driving in the Future

In the author's opinion, about every three to four years there is usually a major design change for family passenger vehicles, and the change is usually based on customers' wants and safety regulations. The future of fleet vehicle design is one in which efficiency, economy, and safety are paramount. Current roadways limit the size of fleet vehicles and consequently limit the size of their cargo. Fuel is one of the main expenses for large truck fleets. The price of fuel may continue to rise, if history is any reference, and a more efficient combustion engine will be required to hold down or at least mitigate the high cost of fuel. Reduction in wind resistance, the rolling resistance of tires, and friction of mechanical parts will be of increasing importance since they directly relate to fuel savings.

Various inventions, such as forward-looking radar, self-parking, and so on, called intelligent transportation systems (ITS), are currently being researched. Another useful system of the future uses infrared to spot pedestrians or animals on roadways long before the driver can see them, especially in adverse weather conditions. Some fleet systems currently use the global positioning system (GPS) to track the speed and location of their tractors and trailers so that it is more difficult for drivers to be off schedule or speeding.

Ride and Vibration

Seating plays an important function in riding performance and vibration dampening. Seat design should be ergonomically correct. The seat's back should be flat vertically and somewhat concave horizontally. Sling-type seats should be avoided because they could cause the weight of the torso and upper legs to be pinched, and the resulting decrease in blood flow could create numbness. Very soft or thickly cushioned seats should also be avoided, since they may cause drivers to become too relaxed when fatigued, compromising safety. The seat back must be inclined so that drivers will be comfortable yet able to keep safety uppermost in their minds (Woodson 1992, 82–85). The seat material should be breathable for air circulation and comfort and have a pattern that will help the driver avoid slipping. It should also be nonflammable, highly resistant to friction and wear, and easy to clean. Foam used in seats should be sufficient to maintain comfort yet not impede visibility or cause *submarining* (sliding forward toward the dashboard) in a frontal collision. Seatbelts must be made of standard materials and must be kept clean and functioning. The seat position must be appropriate for clear and unobstructed vision yet maintain comfort.

It is important to reduce vibration not only for safe vehicle operation but also to avoid driver injury. Usually vibration injuries are subtle at first and become increasingly severe until the source of vibration is eliminated. The smoothness of the vehicle's ride and the construction of the driver's seat play important roles in dampening harmful vibration. The dynamics of vibration begin with an excitation source such as road roughness, tires and wheels, or the engine. The response of the vehicle to this stimulus is the severity of the vibration. A rough road would normally be of short duration while subtler but higher cycles of vibration would usually be over a longer period. Tires can create vibration when their shape is elongated during high-velocity operation. The more misshapen the tire is, the more intense the vibration will be, and the greater the probability of injury is (Kumar 1999, 233–237).

The smoothness of the ride depends on the equilibrium and center of the mass as the mass is rotated.

A vehicle's suspension is the main factor in dampening harmful vibration and creating a smooth ride. Dampening consists of both compression and extension of the vehicles' suspension system. Suspension includes the shock-absorber system, which reduces harmful rebounding and extends the time between cycles, effectively dampening or softening vibration. Evidence of *wheel hopping* are bumps on the tread surfaces of tires. It is caused when the dampening effect of the suspension is not operating properly but allows wheels to rise and fall very quickly and with great force. Since compression and extension usually are not equal, the spatial frequency of this type of dynamic is best when the frequency is further apart rather than close together.

Vibrations can be injurious to the human body, especially if it is exposed to them over a period of time. *Vibration* is the movement back and forth of a body or mass. Any body that is elastic is subject to vibration. *Free vibration* occurs from internal forces only, such as the vibration of an electric hand tool. *Forced vibration* is a result of external forces, such as motor vehicles riding over bumps. Forced vibration is considered to be more harmful. Regular repetition is referred to as *periodic motion*, and the repetition rate is called *frequency*. Normal frequency is determined using a time value, such as per second. Oscillating movements can be repeated regularly or irregularly. A simple periodic or regular repetition is what is known as a *sine wave* or *harmonic wave*. These types of vibrations, which are regular, can be easily determined in a given period of time. Stochastic or random vibrations cannot be so easily determined, except by means of averaging over time. Vibrations can be small or large; the large vibrations are usually considered *peak*. These vibrations can be considered strong or a weak by their displacement, velocity, or acceleration. The displacement is the movement over time; the velocity is the speed over time, while the acceleration is the change of velocity over distinctive periods of time.

Acceleration is usually determined in metric terms as meters per second per second or in standard units, such as feet per second. The easiest way to describe oscillations is by the terms *peak* and *average*. This can be easily seen on an oscilloscope. An oscilloscope is similar to a television screen, but rather than entertaining pictures, harmonic vibration is seen as wavy lines of different displacement over time. Vibration can be measured in various ways; the most accurate method is the root mean square value, which is between the average and peak values. The human response to vibration is dependent upon the frequency of such vibration. The greater the cycle of peaks and average is over time (i.e., one second), the more harmful the vibration. The greater occurrence of vibration that applies to a human body is a random motion, as opposed to a regular or periodic motion.

This motion, when analyzed, is split into spectrums, and the most used spectrum for human analysis is the third octave bandwidth. *Accelerometers* are used to measure human exposure to vibration. The data from the accelerometers is broken down into displacement and velocity, which are more easily understood and analyzed. Vibration is a vector quantity, and the human body has mechanical properties that vary with the direction of the vibration. Vibration is usually measured along three directors, which are classified as the *x*, *y*, and *z* axes. The specific direction of the vibration depends upon the hand tool or other source of vibration such that any harmful vibration effects followed the vector and access of the tool and body region.

The human body does allow absorption of certain amounts of vibration; however, beyond this threshold, vibrations become mechanisms of injury and, in extreme cases, may cause death. We have all become familiar with vibrators that, when used on the back of the neck, have a calming and soothing effect. If this same vibration is kept on the skeletal system for any duration, injury could occur. Injury vibrations depend mainly on their frequency, amplitude, or direction, as well as exposure time (Chaffin et al. 1999).

Occupational Stress

Occupational stress is the reaction of an individual to a threatening or pressing situation (Kroemer 1999, 211–215). Stress comes from many sources and could lead to injury or death depending upon the work being performed. Humans are better than machines at (Kroemer 1999, 157–160):

- detecting low levels of light and sound
- detecting a wide variety of stimuli
- perceiving patterns and the formulation of their general makeup
- detecting signals when the noise level is high
- storing large amounts of information for long periods of time and recalling the appropriate information at the right moment
- using judgment when all of the necessary facts or information are not available
- being flexible when inflexibility is a hazard
- reacting to sudden or unexpected problems and hazards
- solving problems when ingenuity and new methods must be employed
- learning from experience and mistakes
- performing human reasoning

To overcome boredom and fatigue, workers need to be satisfied and challenged. They should be challenged to use their skills—not just be human machines assembling parts. Workers must also feel that the work they perform is meaningful and that they are responsible for the outcome.

Stress may mean different things for different people even within the same field. Stress generally refers to physiological and emotional effects that come with job performance, worry and pressures of the job, and family problems. Stress may include physical problems such as ulcers and cardiovascular problems as well as emotional ones such as fear, jealousy, and moodiness. Stress can also be caused by an overload of work activities acting upon the sensory organs of the body. One well-known, overloaded, computer-like organ is the brain. If workers' brains become overloaded from stress, their training or skill becomes secondary to the handling of the stress or problem. There are times when a human brain receives or perceives one billion bits of information per second, but it is estimated that only about three billion bits can actually be transmitted to the nervous system for action. Of these, approximately sixteen per second become conscious thought in the brain and an even smaller number, one bit per second, is retained by memory.

When the brain becomes overloaded due to a massive influx of information, it is said to be under stress. If it is overloaded with data bits that cannot be processed, the bits are held until the brain can absorb them. If they cannot be absorbed within a relatively short period, the information is no longer accurate and will be distorted, and a possible harmful action could result. Everyone at one time or another exhibits mental fatigue—burnout—when he or she can no longer think clearly or absorb the information necessary to safely perform a task (Kroemer 1999, 191–194).

As with physical fatigue, human movement can also become stressed from mental fatigue, which is complex and has different elements that must be dealt with. A feeling of tiredness when sufficient rest has been received is a sign of mental fatigue, and with the tiredness comes slowed reactions and a slow thought process. It is thought that tiredness is a warning sign. Yawning appears to be a mechanism that increases oxygen intake to the lungs. Oxygen is a crucial element in worker performance, since the brain needs it to survive, and when muscle exertion occurs, oxygen is needed to replenish necessary chemicals. Blood carries oxygen to muscles and also takes waste products such as carbon dioxide and water from the system. Normal basal metabolism is usually sufficient during light physical activities, but when strenuous work is necessary it soon becomes insufficient. To improve the situation, breathing and heart rate increase, and physiological changes in the body can occur since the mind controls body functions. A reduction in output or reduced efficiency of work performance is a sign of mental fatigue, but it can also represent other areas that must be investigated and improved.

Mental fatigue is caused by brain overload, and this overload is more difficult to recover from than physical overload. Mental fatigue appears to be correlated with psychological and emotional stress, while physical overload is caused by work exertion. A factor that may help to increase resistance to mental fatigue is a good mental attitude toward the work performed. Education, experience, good working conditions, and contact with other workers are crucial ways to hold off mental fatigue. A worker's ability to perform a task varies based upon mental stress, fatigue, and distractions. Given the fact that the work function also varies, a combination of mental stress, physical fatigue, distractions, and varying work functions can be a recipe for injury. A worker's ability to perform a specific task should exceed the demand of that task. Boredom is said to be a reaction to a situation where there are too few stimuli, causing a decrease in baseline activity in the human central nervous system and can degrade efficiency and safety. Different people react differently when faced with a monotonous, prolonged task. Monotonous tasks breed boredom and should be interspersed with numerous short breaks and, if possible, a slight change of pace from usual activities.

There are many stressors in the work environment, some of which include the following (Kroemer 1999, 219–225):

- ***Lack of job control.*** If workers cannot participate in determining their own work routines, boredom and stress can occur.
- ***Lack of supervisor support.*** Support of supervisors appears to reduce the effects of stress on workers and should be encouraged whenever possible.
- ***Heavy workload.*** Job distress can be caused by a heavy workload. Too much stress and a heavy workload results in job dissatisfaction and possible loss of employees. If a job has a high rate of turnover, this is usually the reason.
- ***Tasks and demands of the job such as deadlines, efficiency ratings, and so on.*** These play a very important part as stressors and can reduce efficiency.
- ***Lack of job security.*** Lack of job security itself is not usually a problem, but when combined with other stress factors, it becomes a very highly important issue and consequently a high source of job stress.

Fatigue and Shift Work

Stress and fatigue are recipes for disaster, or at least injury. Mental stress and fatigue are as dangerous as their physical partners. Mental activity occurs in any job where incoming information must be processed by the brain. Some brain work, such as thinking, does not involve physical movement. Sometimes brain work can involve a link between a human and a machine. Brain work includes the ability to formulate ideas without acting on them. Humans require perception, interpretation, and the processing of information transmitted by the body's organs. Workers or commercial drivers have an obligation to maintain the highest level of alertness over long periods and to be responsible for making decisions involving the safety of people and equipment while fighting off occasional monotony. The mind may become stressed when more than two bits of information need to be classified and sequenced simultaneously. Fleet drivers run into this type of information overload every time they take the wheel and enter the roadway (Kroemer 1999, 219–225). Bits of information constantly bombard drivers' minds and compete for time. Over a long period this can become quite exhausting. Mental fatigue may take over and, consequently, safety is compromised.

The phases of the human cycle fall into daytime (*ergotropic*) and nighttime (*trophotropic*) categories. A *circadian rhythm* (24-hour cycle) is necessary in order for humans to recycle and regenerate for the next working and relaxation cycles. The cycles are triggered by changes from light to dark, social contacts, work and its associated events, and changes in time as shown on clocks. These events occur on a routine basis, and, consequently, circadian periods are considered routine.

The human body changes during different periods of the circadian cycle:

- Body temperature, heart rate, and blood pressure may fluctuate.
- Respiratory volume and adrenaline production vary.
- Mental ability changes.

During daytime activities all bodily functions and organs are ready for activity and the mind is rested. During nighttime activities, most of these functions are dampened, but they can be regenerated with recuperation and renewal of energy for the next cycle. It is believed that humans are oriented toward daytime performance and nighttime rest. Organizations can perform their own research on this by plotting the number of injuries or near-misses during various time periods and noting whether they occur near the beginning or the end of a shift. Some shift-work studies have found that workers report illnesses 2.5 times more often on evening and night shifts than on day shifts. These illnesses include stomach problems, ulcers, nervous disorders, and intestinal problems. Some can be directly correlated with the type of food ingested during the second or third shift. These problems occur because of disturbances in the sleeping and eating habits of the worker. There is a correlation between chronic fatigue and unhealthy eating habits and increased nervous disorders and stomach ailments. The symptoms of chronic fatigue are loss of appetite, disturbed sleeping, and digestive problems (Kroemer 1999, 191–201).

Younger workers may not sustain illness or injury as often as older workers and may be able to handle disturbance of their circadian rhythm better than older workers. Older workers already have higher probabilities of injury or illness and, coupled with the circadian periods, usually suffer stress more often than younger workers.

Effect of Noise and Vibration

Vibration is the rapid oscillation of waves and can cause injuries to the auditory system as well as to the rest of the body. Vibrations experienced when working with hand power tools can injure the nervous and skeletal systems; the seriousness of the injury depends upon the severity of the vibration and the length of exposure. Vibration is the motion or oscillation of bodies containing mass and elasticity that can move short distances at very fast velocities. *Free vibration* is caused by internal forces of the system, while *forced vibration* is caused by external forces. An example of free vibration is the ear receiving sound waves and the eardrum and the inner ear reacting. There is a limit to the decibels (dB) human ears can withstand over a period of time without permanent injury. Sound waves react with the natural frequency (HZ), resonance occurs and creates *motion amplitude.* Large amplitude within a system is harmful—for example, crystal can be shattered in the presence of very loud sound waves (Kroemer 1997, 320–324).

Motion during vibration can be *harmonic,* meaning that it can be represented by a simple sine wave and is predictable. These predictable motions or frequencies are called *deterministic* if they can be calculated mathematically. *Stochastic* or random vibration is the opposite of deterministic. Random vibration can be determined by averaging the waves. *Oscillation* has magnitude, displacement velocity, and acceleration. For this reason vibration is usually measured with accelerometers. Accelerometers are used to determine the value of the magnitude and are measured in meters per second squared (m/s^2). The quantifying value is so small that it is usually signified by thousands or millions or even greater values of a second squared. Gravity provides an example; at the earth's surface it is approximately 32.2 feet per second squared.

Frequency is the repetitive rate or oscillations per second. These wavelengths of vibration have peak values and average values, which indicate stress relationships. *Peak values* indicate maximum stress but do not consider the time duration, and consequently they are used to determine short-term motion such as shock or impact loading. Average acceleration is mathematically determined by considering cycle time and instantaneous amplitude. *Root mean square* (RMS) is the square root of the mean squared values of the motion of the body. RMS is proportional to the energy of the vibration and is usually between the peak and average values.

How the human body reacts to vibration depends on its frequency. Normally vibrations are applied to the human body randomly. Vibrations act as vectors, and the biomechanical properties of the human body are different depending on the direction of vibration. Therefore, measurement of vibrations must be along the three whole-body axes—*z*-axis (top to bottom), *y*-axis (side to side), and *x*-axis (front to back). These axes must be carefully determined so that the correct threshold of injury can be determined. It should be remembered that vibration is rarely unidirectional and consequently may cause confusion during an analysis if not properly understood.

Injury is caused from the frequency, amplitude, and direction of the vibration over time. If any one of these changes, the probability of injury can decrease or increase. Sensitivity of the human body is as follows:

- A low frequency—1 to 2 Hz—creates sensitivity in the vestibular system—the sensory receptors of the inner ear. This type of vibration may come from ships, cranes, or aircraft.
- A medium frequency—2 to 20–30 Hz—creates sensitivity from a biomechanical standpoint of body resonance. This resonance takes place in body tissues. This type of vibration is caused by vehicles or aircrafts.
- A high frequency—above 20 Hz—creates sensitivity in receptors of the muscles, tendons, and skin. This type of vibration is seen in tools and machinery.

Individual injuries and effects of vibration are based not only on the strength of the vibration and length of time someone is exposed to it but also on the physical condition of the individual. All individuals do not have the same susceptibility to injury, and consequently healthy individuals should adhere to safety guidelines regarding vibration. Vibration in and of itself may not produce injury, but in combination with noise, temperature, posture, or exertion of force, it can create a hazard or injury. Everyone is familiar with motion sickness, either in a motor vehicle or on a ship. Motion sickness is caused by low-frequency vibration and affects the vestibule or receptors of the ear. There are two receptors, the semicircular canal, which is sensitive to angular accelerations, and the otolith organs, which have linear acceleration sensitivity. Motion sickness is believed to occur when these two sensors conflict with each other in relation to head motion.

The human body is said to be a dynamic biomechanical system, but it also models as a linear system within specific ranges of spine oscillations, up to approximately 100 Hz when body tissues have small deformations. The body can be considered a nonlinear model and is said to be better for predicting effects of random and shock vibrations. Vertical vibrations from 5 to 10 Hz cause resonance in the thoracic or abdomen area; vibrations from 20 to 30 Hz affect the head, neck, and shoulders, and vibrations from 30 to 60 Hz affect the eyeballs. Generally, there is less motion in body segments as the frequency increases above 10 Hz.

It is well known that spinal fractures can be caused by compression from large vertical accelerations. Vibrations at lower acceleration levels may cause fatigue fractures in different spinal components. These vibrations also interfere with the nutrition of spinal discs and predispose them to degenerative changes. Normally, degenerative changes are not one-time events but occur over a long period of time, which is one reason older people are more likely to suffer from degenerative discs than younger people. The physiological effects when people are exposed to vibrations include changes in heart rate, blood pressure, ventilation rate, oxygen intake, and so on. The vibrations necessary to produce simple effects are moderate to high in magnitude and in the middle of the frequency range. Vibration applied to a seated person increases the activity of back muscles from the lumbar, thoracic, and cervical regions.

Noise and vibration are harmful over a long period of time and can be harmful even over a short period, depending upon the frequency and level. Vibration affects different areas based upon different frequencies. Various peak-to-peak accelerations affect arm and hand steadiness, which could create a significant hazard. Vibration tolerance limits are classified in vertical or horizontal planes and the following tolerance limits for vertical vibration demonstrate the effects:

- Eight hours can be tolerated for a frequency of 1 Hz to maintain levels of proficiency with an acceleration of 0.6 Gs.
- Four hours can be tolerated for the same frequency with an acceleration of 1.

Important Terms

Basic Definitions of Biomechanical Injury Anatomy Terms (*Stedman's Medical Dictionary* 1997)

Cervical: referring to a segment of the spine, C1 through C7 (vertebrae beginning at the occipital bone and ending at thoracic vertebra T1)

Disc: a jellylike substance between each pair of vertebrae of the spine

delta-v: the change of velocity over time

herniated disc: a disc that protrudes either anteriorly or posteriorly from the vertebrae

LOSRIC: low-speed rear-impact collision

lumbar: referring to a segment of the spine having five vertebrae, L1–L5, between T12 and S1

occipital bone: the bone at the rear base of the skull just above C1

sacrum: an area of the spine with five vertebrae, S1 through S5, between T12 and the coccyx; the buttocks area

thoracic: referring to twelve vertebrae, T1 through T12, between C7 and S1; the upper trunk section

vertebra: a segment of the spinal column. There are seven cervical vertebrae, twelve thoracic, five lumbar, and five sacral.

The following terms and their positions are accepted and used consistently (Andrews 2001, Nahum and Melvin 2002):

- Anterior—Ventral—Forward
- Posterior—Dorsal—Back
- Flexion—Bend forward
- Extension—Bend rearward
- Mid Sagittal Plane—The right and left halves of the body
- Superior—Cranial—Toward the head
- Inferior—Caudal—Toward the feet
- Coronal Plane—The front and rear halves of the body
- Medial—Lateral—Side
- Palmar—Palm side of the hand
- Dorsal—Back of the hand
- Abduction—Movement away from the center of the body
- Adduction—Movement toward the center of the body

Terminology for body position:

- Sagittal—Divides the body into right and left
- Medial sagittal—Close to the center; lateral away from medial
- Corona—Divides the body into the front and back
- Anterior front or ventral side—Posterior back or dorsal side
- Transverse—Divides the body into top and bottom
- Superior—Closest to the head
- Posterior—Closest to the feet
- Limbs, proximal—Closer to the torso
- Limbs, distal—Farther from the torso

Wrist and hand motions:

- Flexion—Bend down
- Extension—Bend up
- Radial deviation—Bend the hand horizontal towards the thumb
- Ulnar deviation—Bend the hand horizontal towards the little finger
- Pronation—Rotation toward palm down
- Supination—Rotation toward palm up

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Additional Reading

Ergonomics and the Mobile Environment*

Tina Minter, MS, CSP, ARM, ALCM
Property & Casualty Risk Specialist
Chubb & Son, a division of Federal Insurance Company
Milwaukee, WI

Introduction

In today's society, working in a mobile environment has become almost as common as working in a traditional office environment. In 2010, 26.2 million people worked from home or remotely for an entire day at least once a month—a figure a representing nearly 20 percent of the U.S. working adult population of 139 million.[1] Over the past several years, mobile work environments and interaction with mobile devices such as laptops, tablets, notebooks and smartphones have increased substantially. In 2010, experts estimated that 17.6 million tablets were sold—a number that was expected to increase more than three-fold in 2011.2 Market projections predict that there could be more than 300 million tablets sold worldwide in 2015, with more than 80 million tablet users in the United States alone.[2,3]

Not only do workers interact with increasing numbers of mobile devices, but they now use their car, van or home as a work area in which to routinely carry out tasks that would previously have been done at a desk in the office. Evidence shows that this trend is probably here to stay. According to a recent survey from Staples Advantage, the business-to-business division of Staples, Inc., employees who telecommute say they feel and work better from home. In fact, 86 percent of telecommuters say they are more productive in their home office.[4]

While working on mobile devices allows workers to be more productive, there are downsides to consider. Mobile and telecommuting computing environments have introduced new areas of ergonomic concern that may threaten workers' well being and lead to increased health costs in the workplace. For example, there are a variety of injuries they may experience as a result of working with the technology in a mobile or home office environment.

Postural Demands

Though the use of mobile devices has increased dramatically, few employers have considered the postural demands on their workers who use laptops, tablets and other mobile devices. Instead, the user ergonomic focus has primarily been on stationary computer use. In theory, a mobile work environment and home office should meet the same health and safety standards as those available at the traditional office. For example, the work surface, chair and accessories should be of comparable quality to that found in the traditional office. The desk should be the appropriate height and sturdy enough to handle the weight of any peripheral equipment placed on it (e.g., computers, printers, fax machines, scanners, etc.). Unfortunately, many home-based workers use the kitchen table, which is not an ideal work surface since it is too high and doesn't allow for proper positioning of the wrists in relation to the keyboard. In addition, workers have little control over ergonomic factors in their mobile work environment while conducting business at other locations outside the home such as the library, Starbucks or even the airport. To address this problem, businesses and managers should monitor the use of mobile devices from an ergonomic perspective to reduce potential injury.

Injuries

Laptop Burn

Laptops can generate a lot of heat since they tend to run fast microprocessors. When the laptop is placed on a solid surface or on a lap, ventilation is greatly reduced because the heat that mainly vents out of the bottom of the device isn't dispersed. As a result, a hot laptop can suffer from reliability problems, and a system that overheats can fail.[5] In addition, a hot laptop can be uncomfortable to use since the heat it generates can be enough to cause superficial skin burns, even through clothing. *The Lancet* medical journal reports the case of a healthy 50-year-old scientist, fully dressed in trousers, who burned his genital area after using a laptop for an hour. Though he did occasionally feel the heat and a burning feeling on his lap and thigh while using the device, he was surprised to find two days later that he had blisters that burst and developed into infected wounds.[6]

Ways to prevent such burns include using a laptop stand that elevates the device for better cooling as well as decluttering the workplace to increase airflow around it. Users could also consider using laptops with built-in fans that generate airflow to keep them cool. Users should also refrain from placing a laptop on the lap for long periods. Those who must use a laptop for a long time should take it off their lap periodically and allow the laptop to cool down.

Mobile Device Neck

The posture adopted by many laptops users even more by tablet and smartphone users puts them at risk of chronic neck and shoulder pain. The tendency is to stand or sit overlooking the device while bending the neck and back to view the screen. Any activity where you hold your head/neck forward in a flexed or bent position for a prolonged period e will cause neck injuries.[7] Because of this injury trend, tablet and laptop users should receive the same ergonomic attention from their employers as desktop computer users did a decade ago. One solution is a laptop stand. Many laptop stands allow for multilevel positioning that improves the ergonomic sight line to the monitor, thus reducing strain on users' shoulders and necks when they view the laptop.

Repetitive Strain Injuries

Repetitive strain injuries are also occurring from overuse of handheld communication devices. These injuries range from "BlackBerry® thumb" and "iPod finger" to "Wiinjuries" and "Nintendinitis," which are more formally known as carpal tunnel syndrome, De Quarvain's tenosynovitis and trigger thumb. Symptoms range from pain and weakness to disability, with the effects being greater in older users who may be more susceptible to inflammation and pain.[8]

When people use laptops, they usually focus on the laptop screen while using the supplied keyboard. As a result, individuals are more likely to tilt their head forward, hunch their backs and use the front portion of their chair. The reasons for this positioning may include reading small character sizes, performing difficult/complicated tasks, working with glare on the screen, or viewing the screen from far away.

To reduce the chance of developing injuries, ergonomic experts advise users to take breaks from electronic devices especially when they notice strain or pain. They can also try to use the auto-text feature or to writer shorter/fewer messages. Those who have pre-existing joint problems should avoid overuse of electronic devices and seek medical assistance if swelling occurs or if symptoms don't go away.

Breaks

In an office environment, there may be many natural breaks, such as discussions with co-workers or a quick walk to the printer, that offer opportunities for a change in body position. But, for those who use mobile devices or work in a home office, there are few, if any, natural breaks that occur throughout the day to help reduce the potential for injury. Extended hours in the same body position or use of repeated motions can lead to various musculoskeletal injuries. Mobile workers should be conscious of taking occasional breaks throughout the day if no natural breaks occur. They can use mobile apps and computer programs that remind them to take breaks or to stretch throughout the day. These apps and programs help breaks up tasks and offer employees a chance to move about, infuse oxygen within the muscles, and lessen body fatigue.

Mobile Equipment Solutions

Laptops

Society's challenge is to start using laptops ergonomically; the good news is that the solutions are relatively simple. For those with a laptop at a desk area, experts recommend using a docking station or port replicator with a peripheral keyboard and mouse along with a separate monitor. A laptop stand or a separate monitor will allow the worker to raise the screen to avoid neck bending. Using a cordless keyboard and mouse will allow the user more flexibility to place the screen appropriately so it is comfortable for the eyes. Using a separate mouse gives the user the opportunity to work with the shoulders relaxed and elbows by the body, thus greatly reducing muscle fatigue.

iPads/Tablets

Currently, the iPad/tablet is not a true substitute for a laptop. Extended typing on-screen can be rather cumbersome, and fingertips may get sore or tender from repeatedly tapping against solid glass as opposed to energy-absorbing keys that allow an added tactile feel not matched by typing on glass. Ergonomic experts recommend that users writing for long periods on a tablet obtain and use a Bluetooth keyboard. Although adding a keyboard increases the bulk and clutter of using a tablet and may ruin the dynamic of working on a lightweight and portable system, it can help mitigate muscle fatigue.

In addition to concerns about typing on a tablet, it can be uncomfortable to hold an iPad for long periods. Tablet and smartphone users are similar to laptop users in that they are very likely to tilt their head forward and hunch their backs while using their devices, although they are usually standing rather than sitting. The many reasons tablet/smartphone users assume this awkward body position include trying to read small character sizes, performing complicated tasks, working with glare on the screen, or viewing the screen from far away. One solution is to use a tablet stand that props up the device so the user can view the screen at eye level. Another suggestion is to use an external keyboard to facilitate easier and more comfortable typing over long periods.

Mobile Computing

Advances in wireless communications and mobile computing have turned today's car into a fully functional office on wheels. While those using their vehicles to perform work may enjoy the benefits of mobility, it may be at the expense of comfort, performance and sometimes even health and safety. In general, vehicles are not ergonomically suitable for working on a laptop. For the mobile worker, ergonomic solutions primarily take the form of devices designed to properly position computers, peripherals and other equipment to avoid problems such as eyestrain, back strain and wrist strain.

The equipment necessary to create an ergonomic workplace in a vehicle includes a keyboard, monitor and storage area. Critical for data entry, keyboards must tilt to provide wrist relief during data entry. While using a laptop mount, the entire laptop will need to tilt, allowing the user to position it at an ideal angle. If a separate keyboard is used, it too should utilize a tilt mechanism. In addition, users should never allow an external keyboard to be loosely stowed in the cab, as it could become a projectile during an accident. Workers should position their monitor to reduce neck strain. Brighter screens are better, but users need to know how to dim the screen for nighttime use. Many times, employees forget creature comforts in the mobile world. A good storage console for a laptop and peripherals will also offer cup holders and a place to store tissues, pencils and paper. Employers should not underestimate the impacts these items can have on worker comfort and job satisfaction.

Telecommuting

With advances in technology (e-mail, Wi-Fi, tablets, smartphones, etc.), more and more employees are opting to work from their private residences on a regular basis (once a week, twice a week or more).

The Benefits

The benefits of telecommuting include savings of over $100 billion in commercial real estate, electricity, employee turnover and absentee costs.[9] In addition, companies increase productivity since employees are allowed to work at their own pace and in an environment with fewer interruptions. There are also several environmental benefits resulting from fewer vehicles on the road: less fuel consumed, less pollution and shorter commute times for those who still go to offices. Telecommuting also allows for "flexing" time for family commitments, which results in increased employee satisfaction. However, it is important that organizations committed to providing employees with telecommuting options also provide work-at-home employees with the same safe environment given to office employees.

The Drawbacks

Because employees are working in the "course and duty" of their employer while working at home or another location, the costs of an injury would be covered under their employer's workers compensation coverage. Thus, when a home office is set up, it should be done with safety in mind, making sure the work area has ergonomically suitable equipment and furniture to help mitigate the risk of a workers compensation claim. Documentation of employers' efforts to provide a safe and ergonomically designed work area will help prove they did their part to ensure their workers' safety.

Summary

Generally, ergonomic risk factors are identified in the office workplace. However, as mobile electronic devices help many workers cut the cords with the traditional workplace, ergonomics are now an important factor for those who telecommute or work in a mobile environment such as their car. These risk factors, left uncontrolled, will result in an increase in ergonomic injuries over time. Uncontrolled ergonomic risks can mean potential liability for those corporations that support telecommuting and a mobile workforce. In fact, many companies may find that the cost of workplace injuries can mean the difference between being competitive or not.

To maintain the health of employees and reduce potential corporate liability, risk and safety professionals must address ergonomic risk factors faced by the telecommuters and a mobile workforce. One approach to mitigating this risk is to develop telecommuting processes, standards and program elements using employee input from a number of corporate disciplines (facilities, HR and other departments). This collective planning process ensures that employees have the proper equipment, workstation setup and other tools to work more productively and safely in their home, a coffee shop or the airport.

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Chapter 5

Basic Economic Analysis and Engineering Economics

Anthony Veltri and James D. Ramsay

LEARNING OBJECTIVES

- Describe the main motivation for applying economic analysis to occupational safety, health, and environmental affairs.
- Articulate the rationale that supports and the logic that is behind incorporating economic analysis findings into safety, health, and environmental investment proposals.
- Describe the safety, health, and environmental investment strategies available to firms and currently being practiced by firms.
- Characterize what is needed to construct a safety, health, and environmental economic analysis model.
- Describe what will be needed for economic analysis to become an on-going practice within the occupational safety and health profession.

The economic aspects of occupational safety, health, and environmental (OS&H) issues and practices are a timely subject to explore, study, and comprehend. Today, OS&H needs are affecting how business decisions are made, and the needs of business are affecting how OS&H decisions are made. This perspective is expected to dramatically change how proposals for investment in OS&H practices will be put together and presented within an organization's overall investment-allocation process. The primary motivation for applying economic analysis to OS&H investment proposals is to become more competitive when the firm makes decisions about which projects to fund. This indicates that investment allocators will make OS&H investments for the same reasons they make other strategic investments within a firm—because they expect those investments to contribute to economic performance. The desire to understand and use OS&H financial analysis has been attracting increasing attention. There are various descriptions of what an OS&H financial accounting system looks like, but essentially all definitions describe the system as a way of enhancing OS&H financial performance.

Economic analysis was defined by Friedman (1987) as the study of trends, phenomena, and information that are economic in nature. While it is understood that the principles of economic analysis will not change much over time, many aspects of how they are applied and under what context they are applied do occur. For example, developments in SHE economic analysis have moved to making the business case covering the social/community/people component of sustainability, supply-chain management, and the lean operation movement. Economic analysis has been used extensively by other internal organizational specialists (i.e., research and development, purchasing, design and process engineering, quality assurance, facility maintenance, operations management, transportation/distribution, and information management). So far, however, OS&H professionals have lagged behind in this effort. The significance of incorporating OS&H elements in the economic analysis of investment proposals was first recognized over a quarter century ago by Professor C. Everett Marcum, founder and curriculum designer of the West Virginia University graduate degree in OS&H Management Studies. Mar-cum reasoned in his course lectures that "The design intent (i.e., functionality and form) of a firm's products and technologies, and its operational processes and services, are first expressed by their economic attractiveness; and foremost judged from an economic point of view; and any other features are secondary to the initial economic review."

Bird (1996), in his book entitled *Safety and the Bottom Line*, expressed a similar reasoning in his concept concerning the Axiom of Economic Association. Bird stated that "A manager will usually pay more attention to information when expressed or associated with cost terminology."

These crucial lines of reasoning have generally evaded the practitioners, professors, and students in OS&H management. While they may be well read in the strategic management practices, technical principles, and regulatory aspects that guide decision making and operating actions for the field, practitioners seldom have studied and used the concepts and methods that underlie their economic logic and attractiveness. Most commonly, books, journal articles, and lectures merely mention these in passing.

Concern about analyzing the economic aspects of OS&H issues and practices initially surfaced in the early 1990s and continues today (Henn 1993, Cohan and Gess 1994, Warren and Weitz 1994, Cobas et al. 1995, Brouwers and Stevels 1995, Mizuki et al. 1996, Van Mier et al. 1996, Lashbrook et al. 1997, Hart et al. 1998, Timmons 1999, Nagel 2000, Warburg 2001, Adams 2002, Behm et al. 2004, Asche and Aven 2004, Oxen-burgh and Merlin 2004, Markku Aaltonen et al. 2006, Santos et al. 2007, Marelli and Vitali 2009). During the last fifteen years, there has been a growing need to understand the economic impact that OS&H issues and practices have on competitive performance. Yet the economics of those issues is one of the least-understood subjects in the industry (Tipnis 1994). Increasingly, U.S. firms have taken steps toward better understanding their competitive impact. This trend is evidenced by the development of OS&H sections of national technology roadmaps (Semiconductor Industry Association 1997–1999, The Microelectronics and Computer Technology Industry Environmental Roadmap 1996, and The United States Green Building Council 2003) that incorporate initiatives to reform the way costs linked to OS&H issues and practices are profiled and by the construction and use of various cost-of-ownership (CoO) models (Venkatesh and Phillips 1992, Dance and Jimenez 1995) that have been developed.

The next chapter will go into detail about cost analysis and budgeting. Therefore, this chapter was developed to present economic analysis as a useful tool for changing how proposals for investment in practices to confront and manage OS&H issues are put together and presented within a firm's overall investment decision-making process. Specifically, this chapter provides (1) a rationale that supports economic analysis and the logic behind incorporating its findings into OS&H affairs and investments, (2) a catalog of OS&H investment strategies available to firms and some currently being used by firms, (3) a blueprint recommended for constructing and using an OS&H economic analysis model, and (4) a summary of elements necessary for economic analysis to become a regular practice in the safety, health, and environmental management profession.

A Rationale For Incorporating Economic Analysis Findings Into Safety, Health, And Environmental Investment Proposals

Showing a relationship between investments in OS&H practices and economic performance can be an elusive undertaking (Behm et al. 2004). The question that continues to challenge internal organizational stakeholders is "Do investments in practices intended to confront and manage OS&H issues contribute to economic performance?" Many OS&H field practitioners and academics have answered yes (Goetzel 2005, The European Agency for Safety and Health at Work 2004, American Society of Safety Engineers 2002, Jervis and Collins 2001, Smallman and John 2001); however, there is no compelling research that provides a *definitive* financial answer. Many internal stakeholders say no (Asche and Aven 2004, Dorman 2000, Shapiro 1998). They are very skeptical about how OS&H economic analyses are conducted; specifically, they question how cost and potential profitability data are collected, calculated, analyzed, interpreted, and reported. The reality may be that OS&H investments do not routinely set up opportunities to make money. At the same time, the opposite stance that OS&H investments seldom provide a financial payoff is also inaccurate. There should be no denying that investing in practices to confront and manage OS&H issues has always been a complicated proposition with very real methodological issues and economic implications. Even so, most firms invest in OS&H practices despite their economic impact, but they should do so knowingly.

Typically, concern for OS&H performance and economic performance have been viewed as separate lines of attack operating independent of and usually in opposition to one another. However, the actual *interdependence* between these concerns increasingly highlights the need for showing some type of an economic relationship. Generally, OS&H professionals have not incorporated economic analysis as a way of showing how investments in these practices contribute to economic performance

(Behm et al. 2004). As a result, left out of the firm's competitive business strategy and excused from internal stakeholder expectations that this function justify its internal and external affairs with an economic perspective, OS&H practices tend to be looked at as a necessary cost of doing business, with little economic payback expected (Veltri et al. 2003a). To say the least, this is not a viable perception for internal stakeholders to bring and hold onto during the investment-allocation process. Only a focus on the results of economic analysis can provide internal stakeholders with the necessary information to set investment-allocation priorities. The emphasis on the results of economic analysis should not be interpreted to mean there is any intention to deemphasize the importance of ensuring compliance with regulatory mandates. Concern for compliance surely exists, as it rightly should, and employing economic analysis is not intended to replace compliance applications. However, to focus *only* on maintaining compliance with OS&H regulations should not be expected to yield positive financial returns. Alternatively, what one attempts to accomplish with economic analysis is to go beyond compliance in ways that provide pertinent quantitative and qualitative economic information about how a firm's organizational activities (i.e., products, technologies, processes, services) tend to create OS&H issues and how strategic investments in innovative practices to confront and manage these issues might offer financial opportunities and reduce liability.

As a rule, the investment decision-making process hinges on a firm's competitive strategy, its research and development capability, its technology wherewithal, and the human means to productively use and protect organizational resources. The analysis used to reach investment-allocation decisions tends to be heavily slanted toward economic aspects. How well economic analyses are conducted and how well analysis findings support a firm's competitive strategy will usually affect how investments are allocated within a firm. During the last 25 years, existing and emerging OS&H issues (e.g., occupational injuries and illnesses, environmental incidents, natural and man-made hazardous exposures, tough government regulatory requirements, pressure from nongovernment interest groups concerning sustainable resource development and use, and long-term contingent liabilities as a result of past operations) are also increasingly affecting how decisions to fund projects are made within a firm. The real dilemma facing financial decision makers is how investment choices to confront and manage OS&H issues can be made in the absence of sound quantitative economic information. Without economic analysis results that detail the estimated cost and potential profitability of investments, even the most zealous OS&H internal stakeholders are left without a means to objectively make fiscally prudent investment-allocation decisions.

The following are beneficial outcomes that should be expected and leveraged when OS&H economic analyses are effectively conducted (Veltri 1997):

1. A refined understanding of the products, technologies, processes, and services that tend to drive OS&H life-cycle costs.
2. A more complete and objective data set on life-cycle costs and profitability potential of OS&H investments, enabling improvements to product, technology, process, and service designs.
3. An enhanced way of determining which OS&H management strategies and technical tactics to pursue and what level of investment will be required.
4. A new investment analysis structure in which fashioning OS&H issues and practices affects how business decisions are made, and in which business needs affect how OS&H decisions are made.

Despite these leveraging opportunities, usually there are internal organizational barriers to overcome when applying economic analysis to OS&H investments. The following are a sample of internal perceptions that OS&H professionals should be expected to confront:

1. An operations-level perspective that OS&H issues linked to the firm's processes are primarily regulatory-compliance-based and play a very small part in the investment-allocation process of the firm.
2. A design engineering-level perspective that sees the existing strategy and methodology for performing economic analysis of OS&H issues and practices that affect new product, technology, and process designs as qualitatively and quantitatively immaterial for enhancing design changes.
3. A senior-level executive perspective that proposals for investments in practices to counteract OS&H issues affecting the firm are not financially structured and reported in a manner that allows them to compete with other investment-allocation alternatives.

Such internal organizational barriers can be significant and must be overcome so that OS&H proposals can compete for the firm's investment dollars. The strategy considered most effective in overcoming these barriers is to employ economic analysis in a manner that discloses both the internal and external OS&H-related costs throughout the productive/economic life cycle of a firm's existing, new, and upgraded organizational activities and reveals the financial impact that investments in OS&H practices have on these organizational activity designs.

Available OS&H Investment Strategies

OS&H professionals who wanted to better understand how investment allocation decisions are made have had to satisfy themselves with professional literature that is nonobjective and fragmented with piecemeal approaches, causing them to be disadvantaged during the investment-allocation process. It is imperative that the forward-thinking OS&H specialist, who is interested in making his/her firm more competitive and in advancing his/her own career, understand how the firm makes strategic investment decisions and how it views investment utilization. However, to accomplish this, the OS&H specialist has to first understand the type of investment strategy being used by his/her firm. Figure 1 offers such a framework by providing a catalog of typical OS&H investment strategies that are available to firms or that are already being practiced by firms. The framework is a derivative work and borrows heavily from other strategy typologies (Miles and Snow 1978, Porter 1980, Adler et al. 1992, Roome 1992, Schot and Fischer 1993, Welford 1994, Chatterji 1995, Ward and Bickford 1996, Epstein 1995, Day 1998, Brockhoff et al. 1999, Stead and Stead 2000, and Coglianese and Nash 2001).

Each of these levels represents a distinct strategy for how a firm typically makes strategic OS&H investment decisions and how they tend to view investment utilization. Together they represent a way of thinking about OS&H investments that goes beyond existing investment strategies, which are at a distinct disadvantage when competing with the firm's other investment options. Investment allocators are usually reluctant to accept qualitative estimates (i.e., compliance audits performed, behavior-based training provided, perception surveys) when deciding to invest in OS&H investment proposals. They prefer quantitative estimates (i.e., cost and profitability potential).

Internal organizational stakeholders constantly face investment choices among alternatives that are linked specifically to changes in the firm's organizational activities. They may have to decide whether to continue or drop a product or service, acquire certain technologies, or reengineer a process. Generally, making these decisions requires conducting economic analyses that provide cost and profitability comparisons among mutually exclusive alternatives (i.e., accepting one alternative means not accepting others). Likewise, investment decisions about OS&H practices require choosing among alternatives that are mutually exclusive and linked to the changes in the firm's organizational activities (e.g., products—substituting regulated occupational safety and health resource inputs with unregulated and perhaps less harmful ones, technologies—employing new environmental toxicity monitoring and detection systems, processes—reengineering to eliminate process waste from resource outputs, or services—modifying supply-chain relationships related to OS&H practices). This results in investment-allocation decisions that are usually based on the direct result of the projected economic impact of the mutually exclusive alternatives under analysis. Economic analysis, then, provides a recommended approach to how one might best present proposals for OS&H investments where economic aspects dominate and drive decision making and where economic effectiveness and efficiency are the criteria for choosing which OS&H issues to confront and manage and in which alternative solutions to make selected investments.

An abridged life-cycle costing method, which features net-present-value financial analysis, is the recommended tool for constructing a OS&H economic analysis model. The rationale for this abridged approach is that internal stakeholders have questioned both the relevance of the full life-cycle costing methodology for the actual business decisions they must make and the efficacy of the full methodology for making business decisions in real time. As a result, most firms are encouraging their OS&H professionals to develop and use a more streamlined method that focuses on internal private costs (i.e., costs incurred from organizational activities that result in product-yield quality and process logistical performance problems, injury/illness and environmental incidents, and liability) rather than on external societal costs (i.e., costs incurred as a result of organizational activities that cause pollution of air, water, or soil; natural resource depletion or degradation; chronic or acute health effects; alteration of environmental habitats; and social/economic welfare effects) to make the economic analysis more relevant and useful for business decision making.

Several abridged life-cycle assessment methods have been described in the literature (Graedel et al. 1995), ranging from primarily qualitative approaches to quantitative ones in which expert judgment, a limited scope, and a system boundary keep the life-cycle assessment effort manageable. Experience demonstrates that life-cycle assessment for a complex manufactured product or an industrial manufacturing process works most effectively when it is done semiquantitatively and in modest depth. Unlike the full life-cycle assessment method, an abridged method is less quantifiable and less thorough. It is also quicker and more practical to implement. An abridged assessment will identify approximately 80 percent of the useful OS&H actions that could be taken in connection with corporate activities, and the amounts of time and money consumed will be small enough that the assessment has a good chance of being carried out and its recommendations implemented. The foundation for the abridged architecture was based on the unabridged life-cycle framework developed by the Society of Environmental Toxicology and Chemistry (SETAC 1991).

Levels of Investment Strategy	
Level 1 Reactive:	Posture is to invest only when required, with attention to responding to government directives or insurance carrier mandates
Level 2 Static:	Posture is to invest cautiously, with specific attention on preventing occupational injuries, illnesses, and environmental incidents from occurring
Level 3 Active:	Posture is to invest assertively, with major emphasis on reducing risk to existing operations, and to lower contingent liability resulting from past operations
Level 4 Dynamic:	Posture is to invest strategically, with major emphasis on counteracting the life-cycle risk and cost burdens linked to the firm's organizational activities carrier mandates

Level 1 Reactive

Strategy for financing the firm's OS&H investments at this level can be characterized as a reactive and resistive arrangement. Access to financial resources is based solely on correcting violations cited by government regulatory agencies and mandates from insurance carriers. Additional financial resources needed for providing technical day-to-day OS&H services are provided when it financially suits the company. Tools for performing economic analysis of OS&H issues do not exist because the firm does not want to, does not think it needs to, or is not aware of the potential cost impact of failing to counteract these issues.

Level 2 Static

Strategy for financing the firm's OS&H investments at this level can be characterized as an informal arrangement. A mentality of funding only as much as others in their industry sector is strongly adhered to. An informal pay-as-you-go funding mentality exists; invest to counteract issues only when trying to reduce the outlays associated with injury/illness and environmental incidents. Investments undertaken for preventing occupational injuries, illnesses, and environmental incidents and to meet compliance with regulations generally do not compete for access to financial resources. However, access to financial resources needed to confront and manage more technically discriminating OS&H issues depends upon the capabilities of the firm's OS&H professionals to assemble internal coalitions of support in order to compete for funding. These technically discriminating prevention initiatives tend to have no clear criteria and pattern of funding, thus subjecting them to unpredictable funding outcomes. Tools for performing economic analysis of OS&H investments are considered by internal organizational stakeholders to be qualitatively and quantitatively immaterial for competing with other investment allocation decision alternatives. OS&H cost accounting practices focus on aggregating cost data, causing costs to be hidden in general overhead accounts rather than included throughout the life cycle of the product, service, technology, or process responsible for their generation. As a result, integrated and concurrent design engineering decision-making capabilities required for aggressively controlling OS&H costs are limited and incomplete.

Level 3 Active

Strategy for financing the firm's OS&H investments at this level can be characterized as an applied arrangement. Access to financial resources tends to be allocated when investment requests are intended to reduce risk to products, technologies, processes, and services; enhance compliance with regulatory standards; reduce contingent liability caused by past operations; and minimize outlays associated with accidents, environmental incidents, lawsuits, and boycotts. The funding level tends to be above others in their industry sector and included in the overall budget of the core business units obtaining the services. Tools for performing economic analysis of OS&H investments are chiefly focused on cost-benefit analysis and payback, and sometimes internal rate of return. Costs are accumulated either through the use of cost accounting systems or through the use of cost-finding techniques and are reported on a regular basis for management information purposes. The cost of incidents are charted and charged back to core business units and incorporated into the firm's budget process. However, profiling the cost and profitability of OS&H issues affecting the organizations products, technologies, processes, and services, and integrating cost information into decision-making, does not occur. This condition results in senior-level executives looking at OS&H issues as nonbusiness issues.

Level 4 Dynamic

Strategy for financing the firm's OS&H investments at this level can be characterized as being self-sustaining and a down-to-business arrangement. A strategically opportunistic funding position is taken; this means having sufficient funding for the long-term, while having the financial wherewithal to remain flexible enough to solve new issues and support research and development and other opportunities for innovation that, over time, will lead to significant OS&H performance gains while advancing measurable business goals. Business strategies and OS&H changes are tightly interwoven; changes in products, technologies, processes, and services affect OS&H, and changes in OS&H issues and practices in turn force product, technology, process, and service changes. Access to financial resources and capital is approved for 3 years (typically related to potential business contribution over the long and short term) and is based on factors and circumstances that are causing the firm to fail in its efforts to protect and use resources productively and on conditions/circumstances under which OS&H pays. Senior-level financial executives desire OS&H strategy and activities to become financially self-sustaining and contribute measurably to company competitiveness. Tools for performing economic analysis of OS&H investments provide reliable and timely information on the full cost burdens associated with the firm's products, technologies, processes, and services over their productive and economic life cycle. Major thinking is performed on how to enhance the efficiency and effectiveness of OS&H spending.

FIGURE 1. Available safety, health, and environmental investment strategies (*Source:* Veltri and Maxwell 2008)

Present-value financial analysis provides the final link in the architecture. As a dollar today is always preferable to a dollar tomorrow, the sheer nature of OS&H initiatives at the work site often take multiple fiscal years to become fully realized. That is, dollars spent today on OS&H programs and activities may not reap or return benefits to the firm for several years. Hence, present-value financial analysis provides the most reliable means of comparing the financial performance of mutually exclusive alternatives when said alternatives fully mature in subsequent fiscal years (Newman 1983). In this way, present-value financial analysis helps to delineate the long-term financial impact of OS&H investments by presenting the after-tax cash flow and the present-cost value of the investment over a sufficient time horizon. The rationale for using net-present-value financial analysis is that many of the traditional financial analysis techniques employed by OS&H professionals, such as payback and rate of return on investment, fail to take the time value of money into consideration. Although useful tools in the financial analysis of investment decisions, exclusive use of these methods can result in making incorrect decisions, such as accepting OS&H project proposals that lose money, or, conversely, rejecting OS&H project proposals that may represent financial opportunities and may reduce contingent liability.

Figure 2 provides an architecture for the OS&H economic analysis model. This architecture is built around three stages: (1) defining and setting all the boundaries necessary for managing the economic analysis; (2) conducting an abridged life-cycle inventory analysis and impact assessment of existing OS&H issues and proposed alternatives, from upfront analyses and the acquisition of capital and the permits through resource and material use, disposal, and closure; and (3) conducting postimplementation reviews that will ensure that the

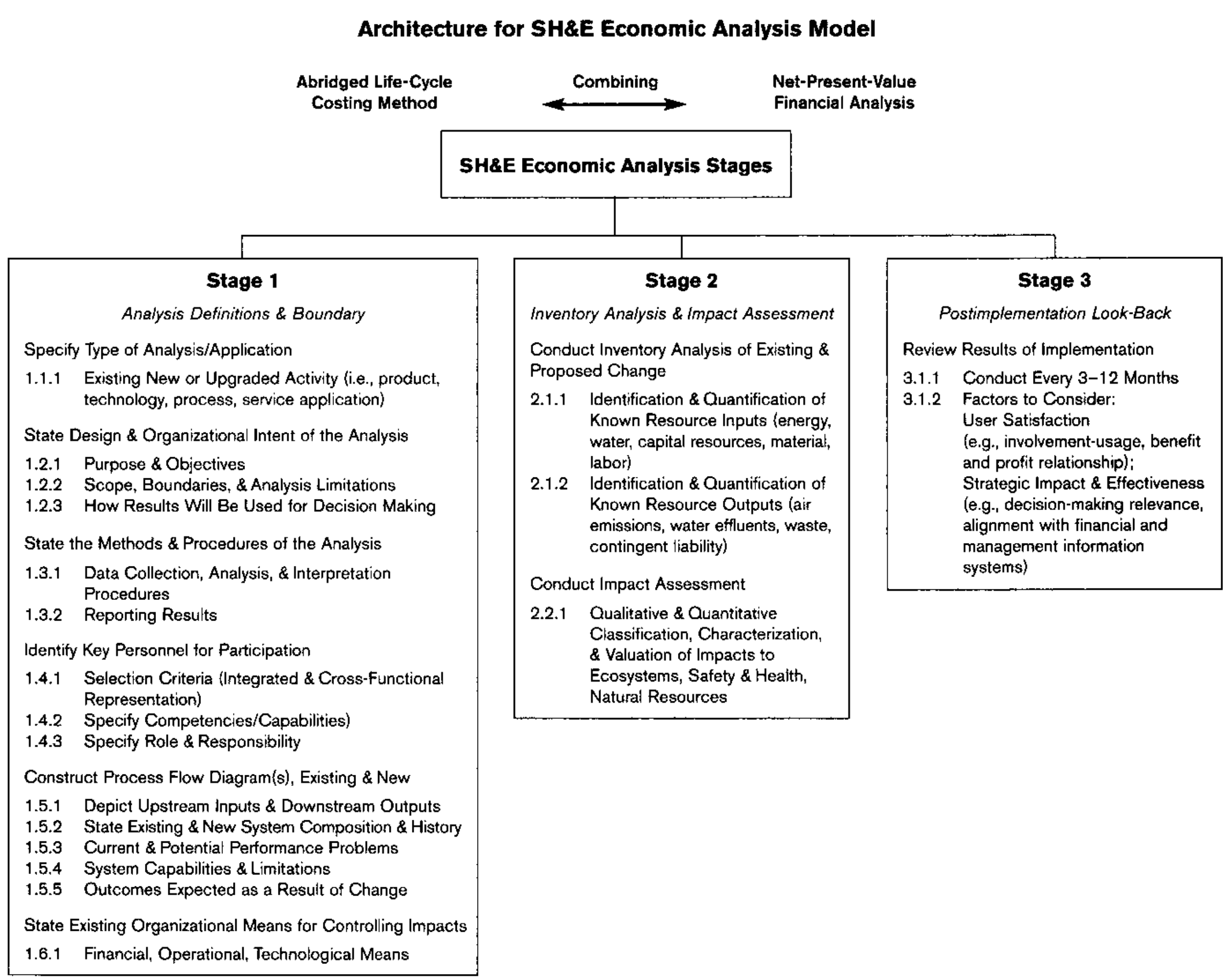

FIGURE 2. Blueprint for constructing a safety, health, and environmental economic analysis model (*Source:* Veltri and Ramsay 2009)

results of implemented solutions are deemed to be in reasonable agreement with the estimated projections.

Stage I: Defining OS&H Economic Analysis Strategy and Boundaries

Defining the OS&H economic analysis strategy and setting its structural boundaries are key aspects of the economic analysis. As outlined in Figure 2, this initial stage should be accomplished through the following five steps. First, the OS&H professional should consider specifying the type of analysis to be conducted, specifically attending to the following components: (a) a description of the existing, upgraded, or new product, technology, process, or service system; (b) the system's expected economic life (i.e., the equivalent of the estimated amount of time that investments in the system can be expected to have economic value or productive uses and the estimated amount of time recurrent savings and reduced contingent liability can be achieved without having to reinvest as the initial investment ages); (c) the firm's hurdle rate (i.e., the required rate of return in a discounted cash-flow analysis that the firm is using for judging investment proposals); and (d) the existing and potential OS&H issues and impacts (e.g., musculoskeletal disorders resulting in workers' compensation claims, CO_2–NOX emissions resulting in global warming potential acidification) that are linked to the firm's activity under analysis.

The second step is to keep the analysis on course and focused. This requires that the design and organizational intent be stated up front. Possible components include: purpose and objectives, key assumptions and analysis limitations, and how information will be used to drive decision-making capabilities.

The third step is to specify the methodology suggested for performing the analysis (i.e., data collection, analysis and interpretation, and reporting procedures). These should be transparent and stated at the outset.

The fourth step is to identify and empower an integrated OS&H economic analysis project team and assist them in carrying out the study. Individuals on this team must be utilized as supportive personnel in order to carry out the project. Note that it is absolutely essential that their assistance be requested and used. Of course, they must be provided with the advisement and encouragement they will need to perform as expected. The team should be cross-functional in makeup and possess skills in finance, design and process engineering, operations, facility management, procurement, legalities, OS&H affairs, and community relations.

The fifth component of this stage is to construct process flow diagrams of the existing organizational activity and the proposed solution change. The process flow diagram should depict upstream inputs and downstream outputs, the existing and new system composition and history, current and potential performance problems, existing and new system capabilities and limitations, and any beneficial outcomes expected as a result of the change.

Stage II: Inventory Analysis and Impact Assessment

Figure 2 shows that the main function of stage two is to conduct an inventory analysis (i.e., the identification and quantification of known resource inputs such as energy, water, capital, resources, materials, and labor, and known outputs such as air emissions, water effluents, waste, and contingent liability) and an impact assessment (i.e., qualitative and quantitative classification, characterization, and valuation of impacts to ecosystems, human safety and health, and natural resources based on the results of the inventory). It is also sensible to provide investment-allocation decision makers with estimates of the firm's ability and means to control or improve the existing OS&H issue. This will add an additional level of robustness to the analysis. Chief factors to assess should include the firm's (1) financial funding capability (i.e., the existing level of funding available to control or improve the OS&H issue: a high level of funding suggests the firm has the financial means to effectively control or improve the issue, whereas a low level of funding suggests the firm has little financial means to affect the issue in the immediate future); (2) human operational capability (i.e., the existing level of human operational wherewithal to control or improve the OS&H issue: a high level of wherewithal suggests the firm has the human means and capability to control or improve the issue, whereas a low level suggests the firm has little human operational means to affect the issue in the immediate future); and (3) available technology (i.e., the existing level of technology that is to control or improve the OS&H issue: a high level of available technology suggests the firm can utilize technology as a way to control or improve the issue, whereas a low level suggests the firm has little technological means to affect the issue in the immediate future).

The use of impact models (e.g., risk and economic) helps guide the decision making and the operating actions that are necessary for keeping the inventory analysis and impact assessment structured and gives a picture of the life-cycle process-flow inputs and outputs linked to the organizational activity under analysis. In addition, it provides investment-allocation decision makers with an understanding of the extent and magnitude of the issue. A large number of risk assessment and analysis models and documents are available for profiling risk impacts and contingent liability linked to the firm's organizational activities.

Stage III: Postimplementation Review

After investing in OS&H practices, it is very important to determine the degree to which the results of the implemented changes are in reasonable agreement with the estimated projections. For example, if a new technology was purchased because of potential reductions in cost and contingent liability, it is important to see if those benefits are actually being realized. If they are, then the economic analysis projections would seem to be accurate. If the benefits are not being obtained, a review to discover what has been overlooked should be performed. A post-implementation assessment helps uncover the reasons why targets were not met. One possible reason could be that economic projections may have been overly optimistic. Knowing this can help analyzers avoid mistakes in economic cost projections in the future. In order to ensure that economic calculations and cost projections are realistic, everyone involved must know that a review of results will take place. Therefore, three to twelve months after a mutually exclusive alternative has become operational, and regularly thereafter, a postimplementation review should be conducted. Factors to be considered in the look-back should include: user satisfaction (i.e., involvement/usage or cost/profit relationship) and strategic impact and effectiveness (i.e., decision-making relevance, alignment with financial and management information technology systems, and organizational objectives).

An economic analysis of a OS&H investment proposal collects cost information associated with the inventory analysis and impact assessment and uses a financial analysis measure for understanding economic impact. The OS&H professional is cautioned that an economic impact analysis of a OS&H investment proposal is only as accurate as the cost information that it collects—quite literally, the euphemism "garbage in, garbage out" applies. In this sense, OS&H professionals are encouraged to work with their finance and accounting colleagues as estimates for necessary costs are obtained. Therefore, a major component of an economic analysis is gathering data to make reasonable estimates of cost. Appendix A provides an outline of usual as well as potentially hidden OS&H life-cycle cost factors and activity drivers that are typically linked to a firm's organizational activities. Estimated costs are referred to in OS&H economic analysis as incremental costs; they are the difference between the after-tax cash flow of the mutually exclusive alternative(s). Net present value (NPV) analysis is the most applicable financial measure for understanding economic impact because it provides the most reliable method for comparing the financial performance of mutually exclusive alternatives on the basis of their projected after-tax cash flows. Net present value analysis can be thought of as the present value of an investment's future cash flows minus the initial investments required to initiate a particular program (or set of programs). Conventional NPV decision-making rules indicate that projects with profitability indices (PI) of greater than 1.0 should be pursued. When comparing multiple project alternatives, those with higher PIs are understood to be financially more attractive than those with lower, albeit positive, PIs. Alternatively, projects with a PI of 0 will recuperate only the cost of the resources required to make the investment, and, conversely, projects with a negative PI represent a financial loss for the investment. Because investment decisions in OS&H are important, proposals should also be supplemented with qualitative information, such as how the investment is expected to maximize sustainable resource development and use practices, enrich the quality of management information, develop human competency and capability, lower contingent liability, maintain regulatory compliance, reduce nongovernment special interest group concerns, and enhance organizational reputation. This type of qualitative information is sufficiently important that it could influence a decision to fund the investment proposal, in spite of the fact that the proposal may not meet the firm's established hurdle rate (i.e., the required return on a discounted investment).

Many firms discontinue their economic analysis after identifying and quantifying resource inputs and outputs. They simply decide to reduce the amount of resource inputs and outputs, taking on a "less is best" strategy rather than investing in the effort necessary for assessing the estimated economic impact. At times, because of the data requirements of impact assessments, it is difficult to relate inventories to an impact analysis and to provide cost and profitability estimates necessary for advancing investment-allocation decision making beyond what has already been collected in the inventory analysis. On the other hand, making an effort to conduct at least a relative impact assessment should provide investment allocators with information that is more meaningful for decision making. For instance, stating the firm's contingent liability (i.e., an estimate of the firm's probability of an accident/incident occurring and the range of cost and economic impact) resulting from increased use and disposal of toxic chemicals is just as easy to understand and assess as providing the change in the reduced level of a chemical input use and/or output waste that was identified and quantified in the inventory analysis. Also, when determining the relative impacts using only inventory analysis, the information provided is limiting when investment-allocation decisions must be made. For example, when the exposure to gases emitted is estimated to be higher for the existing process technology, and the exposure to gases of a different pollutant is also estimated to be higher, which mutually exclusive alternative is preferable for reducing contingent liability and what is the economic impact in terms of cost and profitability potential for making a change? An impact assessment provides investment decision makers with additional information to make such choices. This can be best accomplished by identifying the high risk and cost factors that were linked to the existing situation and performing sensitivity analysis so that the effects of certain changes can be studied and forecast. Using this strategy, benefits and costs are reported in monetary terms and can be estimated over the full life cycle of the product, technology, process, or service under analysis. In addition, a risk and cost impact analysis should be conducted on the countermeasure options to ensure that they do not create additional risk and cost impacts that negate their estimated improvement.

One can readily see that constructing an architecture that is reliably gauging costs and profitability potential can be a complicated and time-consuming process with many aspects to consider. The most essential aspect to consider in constructing an OS&H cost model is assuring that the cost-driver information is reliable. Is there sufficient usable, accurate, and timely information from a good data source to make a determination about its usefulness? A peer-reviewed list of cost drivers that should prove useful can be found in the Appendix.

SUMMARY

Questions and uncertainties related to OS&H issues, practices, and investments tend to create business challenges for a firm's internal stakeholders. It is crucial to understand the existing circumstances that drive these issues, their impacts, and their costs. Knowing how to allocate the investment outlays necessary for confronting and managing these issues and how to evaluate the efficacy of those investment outlays is imperative. In fact, an emerging area of research evolving from OS&H economic analysis is that of OS&H performance measurement, which is concerned with discovering ways to assess the financial benefits of improved OS&H performance. For example, there have been numerous calls in the previous five years for incorporating safety, health, and environmental life-cycle costing in operational settings (DOL 2006, ASSE 2008, and RoSPA 2011). Most organizations do not understand which products, technologies, processes, or services provide more or less value comparative to their existing OS&H costs. Traditional OS&H costing systems tend to suffer from imprecise cost collection, poor analysis and interpretation procedures, and distorted cost reporting. They offer little transparency of what comprises their costs, fail to consider the financial returns that can be expected later from the investment, and thus lose their decision relevance. However, it is interesting that, despite these deficiencies, many organizations continue to invest in OS&H practices, in the authors'experience. It is now time that traditional approaches for justifying OS&H investments yield to a newly fashioned and more economically valued way of thinking.

The last 25 years have shown that changes in a firm's products, technologies, processes, and services are interconnected with its OS&H practices: changes in the firm's products, technologies, processes, and services affect OS&H, and OS&H issues in turn force design changes in the firm's products, technologies, processes, and services. When internal stakeholders are first presented with this connection, many refuse to think about it as an economic opportunity. Viewing it as an additional annoying cost or another regulatory threat, they see it as a move to negotiate a trade-off between operations-related costs and costs related to OS&H practices. This is not the case. In fact, what the safety manager will be able to show internal organizational specialists is that one can set acceptable OS&H performance criteria and then compare the life-cycle cost of ownership for mutually exclusive alternatives that meet or exceed those criteria. The comparative approach will provide them with an improved way of deciding between alternative methods for meeting a specific set of criteria. By looking at investments through the OS&H lens, and looking at OS&H issues and practices through a business lens, internal organizational specialists can derive insights that would otherwise go unnoticed.

The use of economic analysis techniques on OS&H issues is really in its infancy. Economic analysis is not a core accreditation requirement of the Applied Sciences Commission of the Accreditation Board of Engineering and Technology (ABET), which accredits safety programs (ABET 2006). Indeed, the use of economic analysis as applied to OS&H investments currently has reached a point somewhere between the stage of understanding the factors that drive OS&H costs and the stage of using that information to assess economic impact. Any continued developments in this area will require that OS&H professionals put together investment proposals that are based on sound economic analysis and creatively use the results of the analysis for estimating how countermeasure strategies offer opportunities for reducing costs and enhancing revenues. Like any new concept, economic analysis in OS&H areas will go through a predictable life cycle. First, the concept will become increasingly appealing to OS&H professionals as a way to enhance the acceptance of investment proposals and make the business case for OS&H issues and practices. Next, firms will tend to hire outside "experts" with OS&H economic analysis backgrounds to help their internal specialists design an OS&H economic analysis model that is congruent with the way they operate their business and to help pave the way for and steer the use of the model. When the model and its use become functional, OS&H specialists will take over. As the OS&H economic model continues to mature, firms will integrate it into their investment-allocation process. At this point, a firm's ability to respond to OS&H issues associated with its products, technologies, processes, and services with appropriate and economically justified OS&H countermeasures may well become a leading indicator of its competitive advantage in the marketplace.

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APPENDIX

LIFE-CYCLE PHASES, COST FACTORS, AND ACTIVITIES

I. UPFRONT. The phase concerned with profiling the OS&H risk and cost burdens associated with an existing, new, or upgraded product, technology, process, or service over its productive/economic life cycle and designing improvement options that maintain a balance between OS&H priorities and other competing business performance factors. The cost of upfront analysis includes all early-stage studies of risk and cost burdens to bring it to a form for decision making.

Note: Activities performed during the upfront phase are considered one-time costs.

Designing for Safety, Health, and Environment. Consideration of OS&H concerns at an early stage in the design engineering of products, technologies, processes, or services to prevent later risk and cost burdens.

Stage I. Concept Development - Specification Setting
Stage II. Detail Design – Design of Components, Parts, Subassemblies, Process Steps
Stage III. Prototype Manufacture and Testing

II. ACQUISITION. The phase concerned with profiling the costs associated with obtaining OS&H permits and procuring capital equipment necessary for controlling hazardous exposures, preventing/controlling pollution, maintaining regulatory compliance, and enhancing business performance. The costs of acquiring a capital asset or permit include both its purchase price and all other costs incurred to bring it to a form and location suitable for its intended use.

Note: Activity performed and capital costs incurred during the acquisition phase are considered one-time costs.

Obtaining Permits. One-time costs associated with obtaining permits (i.e., wastewater discharge; air emissions; handling, storing, and transporting hazardous substances and associated wastes) for the product, technology, process or service. Examples include:

1. **Permit Review/Approval.** Activities performed to study the procedural and performance requirements of the permit, conduct environmental impact studies, make application, lobby for gaining community approval, and sign off on the permit contract.
2. **Permit Fee.** The direct cost associated with the permit.
3. **Process Reengineering.** Activities performed for reengineering and remodeling the process infrastructure to comply with the procedural and performance requirements of the permit, including capital-related equipment and installation and utility hook-up expenses.

Procuring Capital. One-time costs associated with acquiring capital equipment/areas/structures for the product, technology, process, or service (e.g., emission/effluent control equipment for reducing, neutralizing, and minimizing the volume, toxicity, or hazardous properties of process waste; emission/effluent monitoring devices for providing periodic or continuous surveillance, detection, and recording of exposures to process hazards; reclaim equipment for separating process waste for reuse; treatment/storage/disposal facility equipment for the treatment, storage, recycling, or disposal of waste generated by the process, including the consolidation of waste until shipping.

1. **Equipment Review/Signoff.** Activities performed to study capital equipment alternatives; to qualify suppliers; to develop, negotiate, and sign off on equipment contracts; and to make ready the process to receive equipment.
2. **Equipment Cost.** The direct costs associated with capital equipment, including spare parts.
3. **Process Reengineering.** Activities performed for reengineering and remodeling the process infrastructure to accommodate capital, including equipment installation and utility hook-up expenses.

III. USE/DISPOSAL. The phase concerned with profiling the cost burdens associated with protecting and productively using and disposing of process resources in a manner that prevents injury/illness and environmental incidents and that reduces pollution and waste.

Note: Activity costs incurred in the operational phase are considered annual costs.

Operating Capital (CoO). Annual costs associated with operating/owning capital (i.e., equipment, areas, structures). Examples of costs include: utilities, labor, supplies/materials, maintenance, and preventative maintenance.

Resources Consumed. Annual cost of resources consumed by the product, technology, process, or service that has OS&H life-cycle concerns (e.g., effects on natural resource depletion; reduction of raw material; chemical/gas, energy, and water use).

Consumables Used. Annual cost of consumables used by the product, technology, process, or service (e.g., safety, industrial hygiene, ergonomics equipment or supplies for providing employee protection against exposure to process hazards; environmental protection supplies for preventing and controlling environmental incidents; environmental packaging equipment and supplies for consolidating/protecting/improving the handling of waste; hazardous material management equipment and supplies for providing environmental incident response and recovery services; fire-protection equipment and supplies for providing fire prevention and incident-control services; security equipment and supplies for providing process and factory site-monitoring and surveillance; license/certificates for complying with ESH regulations).

Providing Strategic/Technical Support. Annual costs associated with providing strategic and technical support (e.g., strategic management activities such as process strategic planning, reengineering, auditing-process implementation, and managing contracts); technical support activities (e.g., identifying, evaluating, and controlling exposures to hazards; providing training, environmental emission monitoring, and process, safety, and industrial hygiene inspections; advising on regulatory compliance matters; and assisting in manifesting and record-keeping procedures); research/development activities (e.g., testing, conducting studies, and creating innovative ways to protect and use process resources productively).

Training. Annual costs associated with providing training support in areas such as (1) OS&H law required for maintaining compliance with regulatory laws and standards, and (2) OS&H process specific for developing special competencies and capabilities.

Environmental Processing. Annual costs associated with implementing pollution prevention, reuse, and treatment and disposal strategies (e.g., source reduction by process-optimization activities used for limiting pollution before it occurs, including methods for modification of end product to eliminate a waste; revised operating practices; process-modification changes in raw materials, technology, and equipment; reclaim activities used for reusing and recycling a waste based on a closed and open loop system).

Closed Loop: Implies no further processing of a waste material; it is fed directly into the process step.

Open Loop: Implies the material must be processed (e.g., separating a particular component) prior to being reused.

Abatement activities used to control the physical and/or chemical characteristics of a waste; dilution activities used to change the physical and/or chemical characteristics of a waste after its use to reduce the material's volume and toxicity; waste treatment prior to disposal activities used to change the physical and/or chemical characteristics of a waste after its use to reduce the material's volume and toxicity and to improve handling and storage; waste consolidation/packaging activities used to consolidate and store waste before shipping; waste exchange activities used to transfer or sell waste to a brokerage that could use the waste as a raw material; waste shipping and disposal activities for transporting and disposing of a waste.

IV. POSTDISPOSAL. The phase concerned with profiling the cost burdens associated with monitoring the disposal of waste after the waste has left the control of the process and internal factory site and has been transferred to another company for management.

Note: Activity costs incurred during the postdisposal phase are considered to go beyond the productive life of the product, technology, process, or service.

Managing Waste-Site Compliance. Annual costs associated with assuring that waste-site disposal procedures are managed in a manner that maintains compliance with the waste-site disposal contract agreements and federal and state regulations. Examples include:

1. **Waste-Site Review/Selection.** Activities performed to review and select disposal-site alternatives and to develop, negotiate, and sign off on waste disposal contract agreements.
2. **Compliance Monitoring.** Activities performed to assure that the procedural and performance requirements of the contract agreement and federal and state regulations are in compliance.

V. CLOSURE. The phase concerned with profiling the cost burdens associated with retiring the product, technology, process, or service at the end of its useful life and preparing the area for other productive uses.

Note: Activity costs incurred during the closure phase are considered one-time costs.

Decommissioning. One-time costs associated with retiring the product, technology, process, or service following its useful life. Examples include:

1. **Decommissioning Review.** Activities performed for profiling the risk and cost burdens associated with retiring the manufacturing process or factory site.
2. **Dismantling/Cleanup.** Activities required for disassembling components used in the manufacturing process, arranging for disposal, and conducting clean-up procedures.

3. **Component Shipping and Disposal.** Costs incurred for transporting and disposing of dismantled components.

Remediation. One-time costs associated with remediation and preparing the area for other productive uses.

1. **Remediation Plan.** Activities required for developing ways to prepare the area for other productive uses.

VI. INCIDENTS. The area concerned with profiling the cost burdens associated with environmental contamination, pollution, alteration, occupational injury/illness, and noncompliance fines that adversely affect the product, technology, process, or service. Examples include:

Internalities. Incidents that only affect the internal manufacturing process and tend to result in (1) an adversity or disablement to a resource, (2) incurred direct and indirect costs, and (3) production interruption to the process. Examples of costs include:

Direct Costs. Those costs that can be easily identified and calculated or directly assigned to the incident with a high degree of accuracy (e.g., employee financial compensation (both current and reserved), damaged manufacturing property resources, capital replacement expenditures, incident fines, and legal expenses).

Indirect Costs. Those costs that can be intangible and difficult to calculate in the short term (e.g., incident investigation, production delays, loss of training investment, loss of future contribution of employee, replacement of resources, claims management, incident response/recovery/remediation, and business resumption).

Externalities. Internal incidents that affect the outside environment and tend to result in (1) air, water, soil pollution, (2) resource depletion/degradation, (3) chronic/acute health effects, (4) environmental habitat alteration, and (5) social/economic welfare effects.

Direct Costs. Those costs that can be easily identified and calculated or directly assigned to the incident with a high degree of accuracy (e.g., financial compensation for damaged environmental resources, fines, and legal expenses).

Indirect Costs. Those costs that can be intangible and difficult to calculate in the short term (e.g., incident investigation, incident recovery/remediation costs, and claims management).

Noncompliance Fine Facilitation. Citations issued for failing to comply with federal, state, or local environmental, safety, and health agencies.

Direct Costs. Those costs that can be easily identified and calculated or directly assigned to the fine with a high degree of accuracy (e.g., financial payment for the citation; making the facility and the process ready to comply, including any capital expenditures, materials, labor, legal fees, and research).

Indirect Costs. Those costs that can be intangible and difficult to calculate in the short term (e.g., activities needed to study and contest the fine).

Chapter 6

Cost Analysis and Budgeting

Fran Sehn

LEARNING OBJECTIVES

- Understand the problem of traffic crashes and the types of loss analyses needed to identify and minimize the problem.
- Determine a cost-benefit-analysis methodology for fleet safety initiatives.
- Be able to provide useful guidelines regarding what to include in budgeting for fleet safety
- Learn how to analyze the cost of driver training.
- Understand the factors that influence the cost of vehicle maintenance (inspection and repair).

In April 2006, U.S. Transportation Secretary Norman Y. Mineta declared that highway traffic deaths were a "national tragedy" and called on all Americans to respond by wearing safety belts, using motorcycle helmets, and driving sober. According to a report from the Department of Transportation's National Highway Traffic Safety Administration (NHTSA), 33,561 people died on the nation's highways in 2012, up from 32,479 in 2011. Injuries increased from 2.17 million in 2011 to 2,362 million in 2012, an increase of 3.3 percent (NHTSA 2014). Fifty-two percent of passenger-vehicle occupants who died in 2012 were unbelted (NHTSA 2014), despite the fact that overall safety-belt use is at an historic high of 86 percent nationwide in 2012 (NHTSA 2014).

When NHTSA reported safety-belt use at 82 percent in 2006, Mineta stated, "Every year this country experiences a national tragedy that is as preventable as it is devastating . . . We have tools to prevent this tragedy—every car has a safety belt, every motor- cycle rider should have a helmet, and everyone should have enough sense to never drive while impaired" (NHTSA 2006).

This NHTSA report also projected an eighth-straight year of increased motorcycle fatalities. In 2012, 4957 motorcyclists died, a 7.1 percent increase over 2011, when there were 4630 fatalities (NHTSA 2014). Motor vehicle crashes were leading cause of death for age 4 and every age 11 through 27 (NHTSA 2014).

Traffic crashes come at an enormous cost to society, Mineta noted. NHTSA estimates show that highway crashes cost society $230.6 billion a year, about $4820 per person (NHTSA 2006).

While there have been several statistically significant decreases in the estimated number of people injured annually, 2012 shows the first statistically significant increase since 1995. The fatality rate per 100 million vehicle miles traveled (VMT) increased 3.6 percent from 1.10 per million VMT in 2011 to 1.14 in 2012. The overall injury rate increased by 6.7 percent from 75 per 100 million VMT in 2011 to 80 in 2012 (NHTSA 2014).

The data for 2012 reflected higher fatality and injury rates: 1.14 deaths per million miles traveled in 2012 (1.10 deaths were reported for 2011). In addition, the composition of fatalities changed little from 2011 to 2012, with a 0.89 percent in passenger vehicle occupants in 2012 as opposed to 0.88 in 2011 and 0.83 in 2010; the same (0.73) for light trucks in 2011 and 2012 and 0.86 in 2010, 0.26 in large trucks in 2012 versus 0.24 in 2011 and 0.18 in 2010, and 23.97 for motorcycles in 2012, a decrease from 24.94 in 2011 and 24.40 in 2010 (NHTSA 2014). The number of people injured in motor-vehicle crashes in 2012 increased for the first year since 2005, with 145,000 more injuries in 2012 than in 2011 (NHTSA 2014). According to NHTSA alcohol-impaired driving fatalities in 2012 stood at 10,322, up from 9865 in 2011 (an increase of 4.6 percent) (NHTSA 2014). Overall, 18 states and Puerto Rico saw a decline in the number of alcohol-impaired driving fatalities between 2011 and 2012 (NHTSA 2013).

> Today's numbers reflect the tangible benefits of record seat-belt use and strong antidrunk-driving enforcement campaigns. But we are still losing more than 30,000 lives a year on our highways, and about a third of these involve drunk driving. We will continue to work with our state partners to strictly enforce both seat belt use and anti-drunk driving laws across this nation, every day and every night. (NHTSA 2010)

How Business Views Traffic Safety

Guidelines for Employers to Reduce Motor Vehicle Crashes, funded by the Occupational Safety and Health Administration (OSHA), NHTSA, and the Network of Employers for Traffic Safety (NETS) state (OSHA, NHTSA, and NETS 2006):

> Motor vehicle crashes cost employers $460 billion annually in medical care, legal expenses, property damage, and lost productivity. They drive up the cost of benefits such as Workers' Compensation, Social Security, and private health and disability insurance. In addition, they increase the company overhead involved in administering these programs.

The Bureau of Labor Statistics (BLS), in 2012 final data, indicated that more work-related fatalities resulted from transportation incidents than from any other type of event. Roadway incidents accounted for 60 percent of the fatal transportation incidents; 565 deaths, or 29 percent, were as a result of collisions with other vehicles (BLS 2014). Drivers/sales workers and truck drivers accounted for 813 fatalities in 2012. This is a rate of 24.3 per 100,000 employed. Transportation incidents accounted for 60 percent of the 353 workers killed in 146 multiple-fatality events (BLS 2014).

NHTSA has determined that "the average crash costs an employer $16,500. When a worker has an on-the-job crash that results in an injury, the cost to their employer is $74,000. Costs can exceed $500,000 when a fatality is involved. Off-the-job crashes are costly to employers as well" (OSHA, NHTSA, and NETS 2006).

These costs are highlighted in a final report for the Federal Motor Carrier Safety Administration. The report noted (Zaloshnja and Miller 2002):

- The cost of crashes with two or more trailers involved was the highest among all crashes—$88,483 per crash.
- Among crashes of all types of trucks (including a single large truck, tractor-trailer or multiple trailers, and buses), bus-involved crashes had the lowest cost—$32,548 per crash. (NOTE: *large trucks* means tractor-trailers, single-unit trucks, and some cargo vans over 10,000 pounds.)
- The cost per crash with injuries averaged $164,730 for large-truck crashes and $477,043 for bus crashes.
- The crash cost per 1000 truck miles was $157 for single-unit trucks, $131 for single combination trucks (tractor and trailer), and $63 for multiple combinations—tractor and multiple trailers.
- The average annual cost of large-truck crashes from 1997–1999 exceeded $19.6 billion, including $6.6 billion in productivity losses, $43.4 billion in resource costs, and $419.6 billion in quality-of-life losses.

These cost estimates exclude mental healthcare costs for crash victims, roadside repair costs, cost of cargo delays, earnings lost by family and friends caring for the injured, and the value of schoolwork lost. These data are prime examples of the hidden costs of crashes and their related outcomes.

Social Media Accident Causation

The use of cell phones has become as common as any other human activity in many countries, including the United States. This wireless communication device is both a benefit and a hinderance to driving activities. The cell phone can be used for emergency contact, but it is often involved in distracting the driver. The National Safety Council (NSC) research shows cell-phone use while driving has been associated with quadrupling the crash risk. The NSC estimated that 28 percent of all crashes per year involve talking on cell phones and texting while driving—accounting for 1.6 million crashes (NSC 2010). According to the the NHTSA, an estimated 11 percent of drivers in 2008 were talking on cell phones at any given time. The NHTSA statistics also show that, in 2008, approximately 5870 people were killed and an estimated 515,000 were injured in crashes in which there was at least one reported form of driver distraction. Drivers younger than 20 years of age accounted for about 16 percent of those deaths (NHTSA 2011).

The same article indicated that, in 1999, only 3 percent of NSC members reported any type of cell-phone ban. Ten years later, nearly 50 percent reported either handheld or full cell-phone bans.

Is banning cell-phone use the answer? In a recent visit to California for business, this author witnessed the impact of no use of handheld cell phones in the Los Angeles area on three major highways used during the business trip. Asking a client what has encouraged non-use the most, the simple answer was "the fine if caught."

Overview of Distracted Driving

The NHTSA states that driver distraction could pose a serious and potentially deadly danger. In 2009, 5474 people were killed on U.S. roadways and an estimated 448,000 were injured in motor-vehicle crashes that were reported to have involved distracted driving. *Distracted driving* is any nondriving activity that a person engages in, which has the potential to distract him or her from the primary task of driving and increases the risk of crashing.

Distracted driving comes in various forms, such as cell-phone use, texting while driving, eating, drinking, talking with passengers, as well as using in-vehicle technologies and portable electronic devices. Daydreaming and dealing with strong emotions are less obvious forms of distractions.

There are three main types of distraction:

- ***Visual:*** Taking your eyes off the road
- ***Manual:*** Taking your hands off the wheel
- ***Cognitive:*** Taking your mind off what you are doing

Texting while driving is alarming because it involves all three types of distraction (NHTSA n.d.).

The Federal Motor Carrier Safety Administration (FMCSA) states (FMCSA 2010):

> New technologies are available that provide objective measures of driver behavior. These in-vehicle technologies are able to provide continuous measures on a wide variety of driving behaviors previously unavailable to the fleet safety manager . . . If behavioral approaches can be integrated with technologies that monitor behavior, fleet safety managers would have an effective tool to improve safety-related behaviors.

This concurs with the information in this chapter that commercial truck and bus drivers typically work alone and in relative isolation, and therefore require alternative strategies.

Using Telemetrics as a Tool to Solve the Problem

In *An Introduction to Telematics*, Tam states (Tam n.d):

> The data captured by the devices commonly include the vehicles location, speed, driver behavior, and vehicle diagnostics data determined by the telematics system. The fleet safety manager can in advanced solutions view data in real time. . . . Virtually any fleet operation can benefit from adoption of fleet safety telematics solutions. These solutions enable drivers and companies to proactively reduce costs, improve fleet safety and increase productivity. Some fleet safety solutions also involve installation of an in-vehicle video camera to capture evidence of collisions and other important driving events. The data obtained can be combined with other in-depth analytics to help identify root causes and driving behavior. The fleet safety reports, viewed over an extended period of time are excellent tools for supervisors to use in conducting targeted driver training and counseling programs.

Loss Analysis Methods

The employee's cost due to a crash can be significant. The loss of wages and medical costs beyond what Workers' Compensation Insurance pays, as well as pain and suffering, are a burden to the employee, the employee's family, and the employer.

Methods of determining employer costs are varied. Several tools are available to fleet safety professionals to analyze these costs. The goal of analysis should be to determine problem areas, gaps in the safety program, and initiatives needed to minimize future crashes.

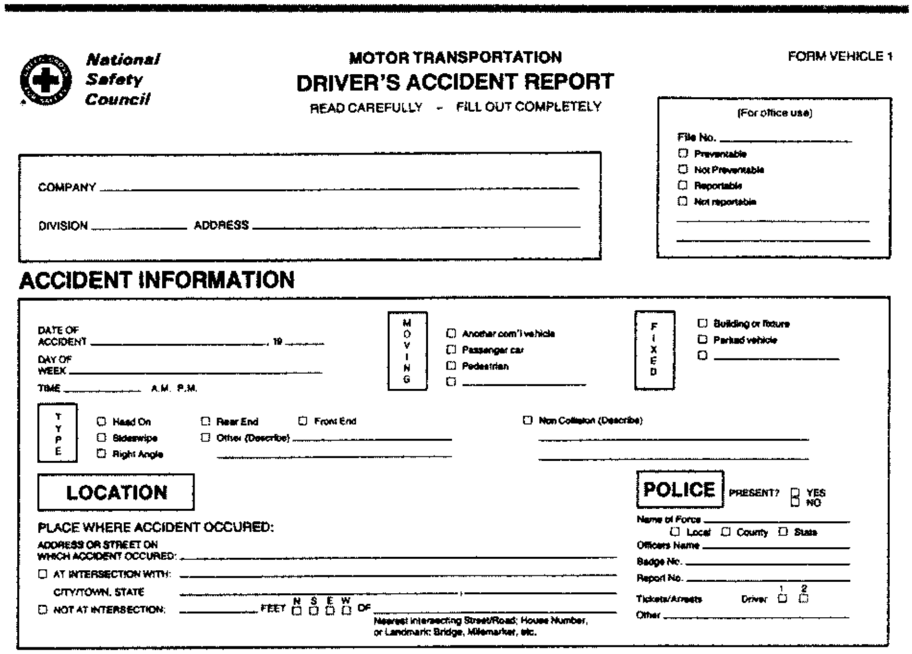
When a crash occurs, an initial investigation to determine the cause of the incident should take place. One method employers use for this inquiry includes an incident investigation form (see Figures 1A–E) (NSC 1996).

An effective investigation or analysis of a crash/incident will provide fleet safety professionals with information that can be used to determine

- the root cause of the crash/incident
- its preventability
- appropriate countermeasures to prevent a recurrence

Safety Measurement System (SMS)

In 2010, the FMCSA introduced the safety measurement system (SMS), a new risk-control measurement system


National Safety Council

MOTOR TRANSPORTATION
DRIVER'S ACCIDENT REPORT
READ CAREFULLY - FILL OUT COMPLETELY

FORM VEHICLE 1

(For office use)
File No.
☐ Preventable
☐ Not Preventable
☐ Reportable
☐ Not reportable

COMPANY
DIVISION ADDRESS

ACCIDENT INFORMATION

DATE OF ACCIDENT , 19
DAY OF WEEK
TIME A.M. P.M.

MOVING: ☐ Another com'l vehicle ☐ Passenger car ☐ Pedestrian ☐

FIXED: ☐ Building or fixture ☐ Parked vehicle ☐

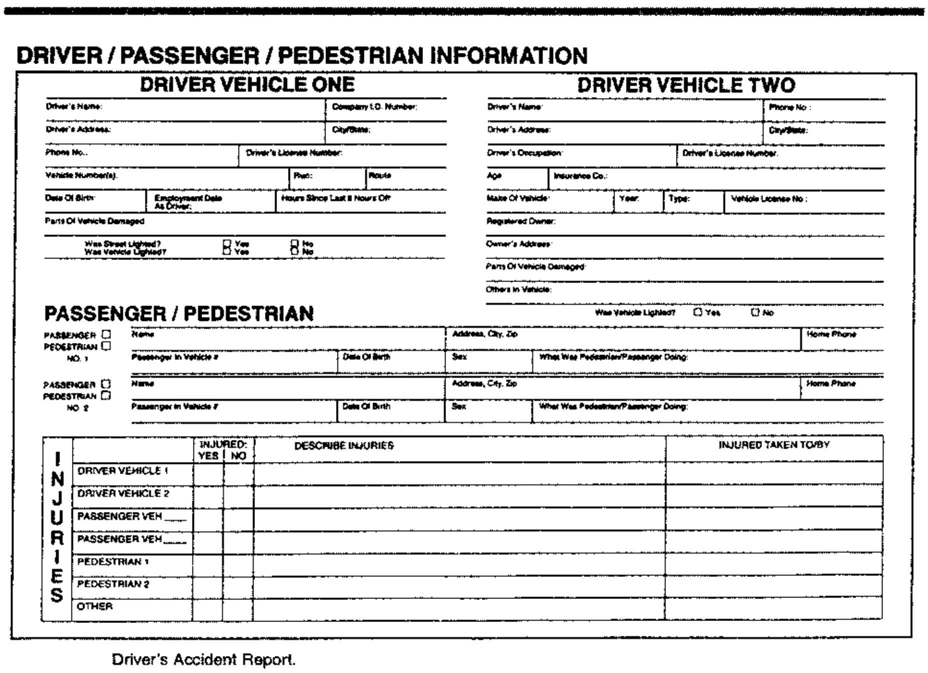
TYPE: ☐ Head On ☐ Rear End ☐ Front End ☐ Sideswipe ☐ Other (Describe) ☐ Right Angle ☐ Non Collision (Describe)

LOCATION

PLACE WHERE ACCIDENT OCCURED:
ADDRESS OR STREET ON WHICH ACCIDENT OCCURED:
☐ AT INTERSECTION WITH:
CITY/TOWN, STATE
☐ NOT AT INTERSECTION: FEET N S E W ☐ ☐ ☐ ☐ OF
Nearest intersecting Street/Road; House Number, or Landmark: Bridge, Milemarker, etc.

POLICE PRESENT? ☐ YES ☐ NO
Name of Force
☐ Local ☐ County ☐ State
Officers Name
Badge No.
Report No.
Tickets/Arrests Driver 1 ☐ 2 ☐
Other

FIGURE 1A. Accident information (*Source: Driver's Accident Report*, with permission of the National Safety Council 1996)


DRIVER / PASSENGER / PEDESTRIAN INFORMATION

DRIVER VEHICLE ONE
Driver's Name: Company I.D. Number:
Driver's Address: City/State:
Phone No.: Driver's License Number:
Vehicle Number(s): Plan: Route
Date Of Birth: Employment Date As Driver: Hours Since Last 8 Hours Off
Parts Of Vehicle Damaged
Was Street Lighted? Was Vehicle Lighted? ☐ Yes ☐ No

DRIVER VEHICLE TWO
Driver's Name: Phone No.:
Driver's Address: City/State:
Driver's Occupation: Driver's License Number:
Age Insurance Co.:
Make Of Vehicle: Year: Type: Vehicle License No.:
Registered Owner:
Owner's Address:
Parts Of Vehicle Damaged:
Others In Vehicle:
Was Vehicle Lighted? ☐ Yes ☐ No

PASSENGER / PEDESTRIAN
PASSENGER ☐ PEDESTRIAN ☐ NO. 1 — Name; Address, City, Zip; Home Phone; Passenger In Vehicle #; Date Of Birth; Sex; What Was Pedestrian/Passenger Doing:
PASSENGER ☐ PEDESTRIAN ☐ NO. 2 — Name; Address, City, Zip; Home Phone; Passenger In Vehicle #; Date Of Birth; Sex; What Was Pedestrian/Passenger Doing:

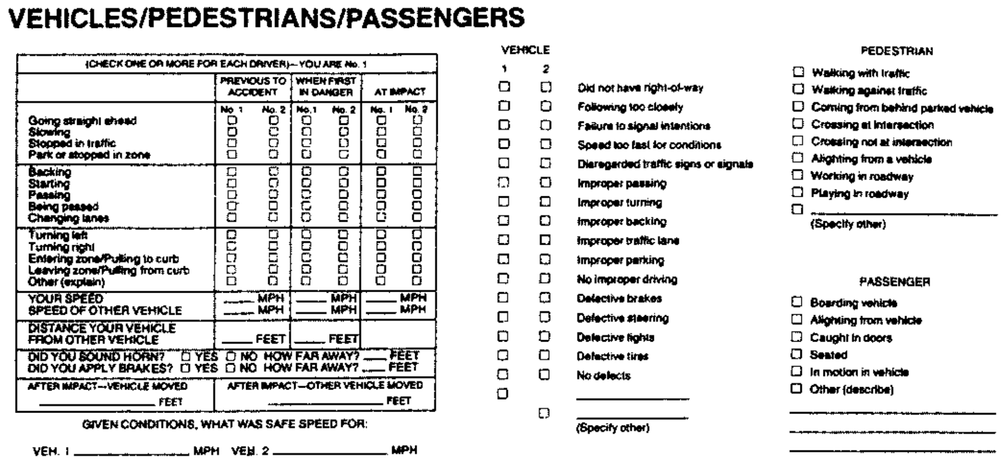
INJURIES	INJURED: YES	NO	DESCRIBE INJURIES	INJURED TAKEN TO/BY
DRIVER VEHICLE 1				
DRIVER VEHICLE 2				
PASSENGER VEH ___				
PASSENGER VEH ___				
PEDESTRIAN 1				
PEDESTRIAN 2				
OTHER				

Driver's Accident Report.

FIGURE 1B. Driver/passenger/pedestrian information (*Source: Driver's Accident Report*, with permission of the National Safety Council 1996)

that replaced its older SafeStat system. SMS quantifies the on-road safety performance of carriers and drivers. The primary intent is to identify candidates for interventions, determine the specific safety problems the carrier or driver exhibits, and monitor whether safety problems are improving or worsening. SMS is integral to the compliance, safety, and accountability operational model.

SMS uses the motor carrier's data from roadside inspections, including all safety-based violations, state-reported crashes, and the federal motor carrier census to



VEHICLES/PEDESTRIANS/PASSENGERS

(CHECK ONE OR MORE FOR EACH DRIVER)—YOU ARE No. 1

	PREVIOUS TO ACCIDENT No. 1	PREVIOUS TO ACCIDENT No. 2	WHEN FIRST IN DANGER No. 1	WHEN FIRST IN DANGER No. 2	AT IMPACT No. 1	AT IMPACT No. 2
Going straight ahead	☐	☐	☐	☐	☐	☐
Slowing	☐	☐	☐	☐	☐	☐
Stopped in traffic	☐	☐	☐	☐	☐	☐
Park or stopped in zone	☐	☐	☐	☐	☐	☐
Backing	☐	☐	☐	☐	☐	☐
Starting	☐	☐	☐	☐	☐	☐
Passing	☐	☐	☐	☐	☐	☐
Being passed	☐	☐	☐	☐	☐	☐
Changing lanes	☐	☐	☐	☐	☐	☐
Turning left	☐	☐	☐	☐	☐	☐
Turning right	☐	☐	☐	☐	☐	☐
Entering zone/Pulling to curb	☐	☐	☐	☐	☐	☐
Leaving zone/Pulling from curb	☐	☐	☐	☐	☐	☐
Other (explain)	☐	☐	☐	☐	☐	☐
YOUR SPEED	___ MPH		___ MPH		___ MPH	
SPEED OF OTHER VEHICLE	___ MPH		___ MPH		___ MPH	
DISTANCE YOUR VEHICLE FROM OTHER VEHICLE	___ FEET		___ FEET			

DID YOU SOUND HORN? ☐ YES ☐ NO HOW FAR AWAY? ___ FEET
DID YOU APPLY BRAKES? ☐ YES ☐ NO HOW FAR AWAY? ___ FEET

AFTER IMPACT—VEHICLE MOVED ___ FEET
AFTER IMPACT—OTHER VEHICLE MOVED ___ FEET

GIVEN CONDITIONS, WHAT WAS SAFE SPEED FOR:

VEH. 1 ___ MPH VEH. 2 ___ MPH

VEHICLE

1	2	
☐	☐	Did not have right-of-way
☐	☐	Following too closely
☐	☐	Failure to signal intentions
☐	☐	Speed too fast for conditions
☐	☐	Disregarded traffic signs or signals
☐	☐	Improper passing
☐	☐	Improper turning
☐	☐	Improper backing
☐	☐	Improper traffic lane
☐	☐	Improper parking
☐	☐	No improper driving
☐	☐	Defective brakes
☐	☐	Defective steering
☐	☐	Defective lights
☐	☐	Defective tires
☐	☐	No defects
☐		___
	☐	___ (Specify other)

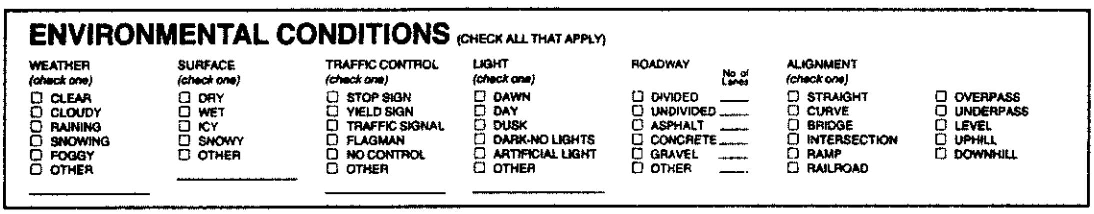
PEDESTRIAN

☐ Walking with traffic
☐ Walking against traffic
☐ Coming from behind parked vehicle
☐ Crossing at intersection
☐ Crossing not at intersection
☐ Alighting from a vehicle
☐ Working in roadway
☐ Playing in roadway
☐ ___ (Specify other)

PASSENGER

☐ Boarding vehicle
☐ Alighting from vehicle
☐ Caught in doors
☐ Seated
☐ In motion in vehicle
☐ Other (describe)

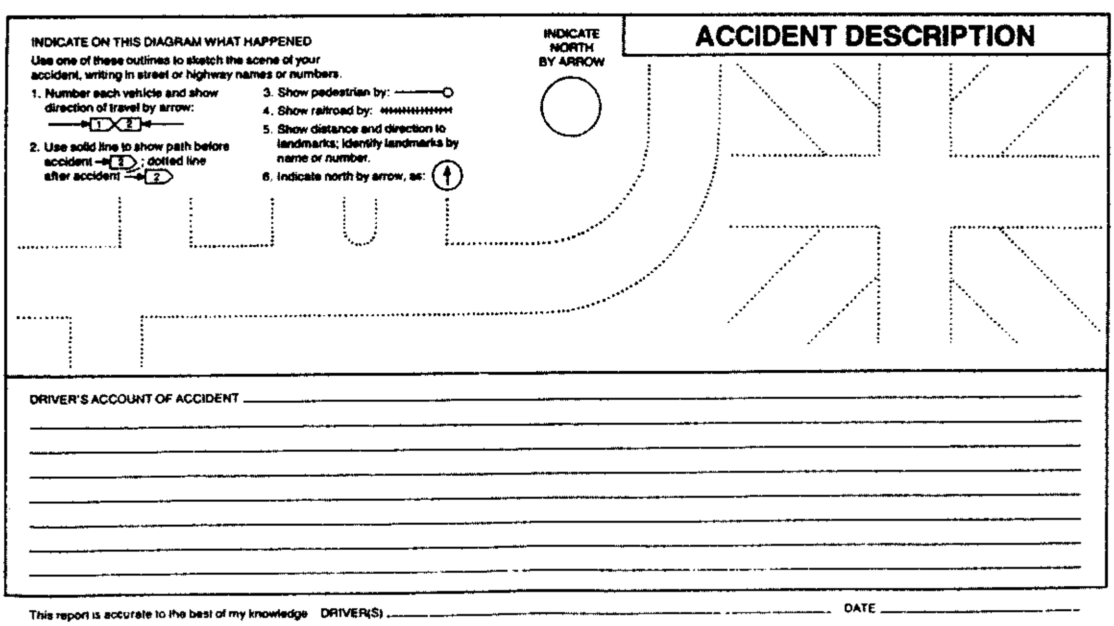
FIGURE 1C. **Vehicles/pedestrians/passengers information** (*Source: Driver's Accident Report*, with permission of the National Safety Council 1996)



ENVIRONMENTAL CONDITIONS (CHECK ALL THAT APPLY)

WEATHER (check one)	SURFACE (check one)	TRAFFIC CONTROL (check one)	LIGHT (check one)	ROADWAY (No. of Lanes)	ALIGNMENT (check one)	
☐ CLEAR	☐ DRY	☐ STOP SIGN	☐ DAWN	☐ DIVIDED ___	☐ STRAIGHT	☐ OVERPASS
☐ CLOUDY	☐ WET	☐ YIELD SIGN	☐ DAY	☐ UNDIVIDED ___	☐ CURVE	☐ UNDERPASS
☐ RAINING	☐ ICY	☐ TRAFFIC SIGNAL	☐ DUSK	☐ ASPHALT ___	☐ BRIDGE	☐ LEVEL
☐ SNOWING	☐ SNOWY	☐ FLAGMAN	☐ DARK-NO LIGHTS	☐ CONCRETE ___	☐ INTERSECTION	☐ UPHILL
☐ FOGGY	☐ OTHER	☐ NO CONTROL	☐ ARTIFICIAL LIGHT	☐ GRAVEL ___	☐ RAMP	☐ DOWNHILL
☐ OTHER		☐ OTHER	☐ OTHER	☐ OTHER ___	☐ RAILROAD	

FIGURE 1D. **Environmental conditions information** (*Source: Driver's Accident Report*, with permission of the National Safety Council 1996)



INDICATE ON THIS DIAGRAM WHAT HAPPENED

Use one of these outlines to sketch the scene of your accident, writing in street or highway names or numbers.

1. Number each vehicle and show direction of travel by arrow:
2. Use solid line to show path before accident; dotted line after accident
3. Show pedestrian by:
4. Show railroad by:
5. Show distance and direction to landmarks; identify landmarks by name or number.
6. Indicate north by arrow, as:

INDICATE NORTH BY ARROW

ACCIDENT DESCRIPTION

DRIVER'S ACCOUNT OF ACCIDENT ___

This report is accurate to the best of my knowledge DRIVER(S) ___ DATE ___

FIGURE 1E. **A schematic or diagram of the collision/crash** (*Source: Driver's Accident Report*, with permission of the National Safety Council 1996) quantify performance in the following behavior analysis and safety improvement categories (BASICs):

1. **Unsafe Driving:** Operation of commercial motor vehicles (CMVs) by drivers in a dangerous or careless manner. Example violations include speeding, reckless driving, improper lane change, and inattention (FMCSR Parts 392 and 397).
2. **Fatigued Driving:** (Hours of Service): Operation of CMVs by drivers who are ill, fatigued, or in noncompliance with the hours-of-service (HOS) regulations. This BASIC includes violations of regulations pertaining to logbooks, as they relate to HOS requirements, and the management of CMV driver fatigue. Examples of violations include exceeding HOS, maintaining an incomplete or inaccurate logbook, and operating a CMV while ill or fatigued (FMCSR Parts 392 and 395).
3. **Driver Fitness:** Operation by drivers who are unfit to operate a CMV due to lack of training, experience, or medical qualifications. Examples of violations include failure to have a valid and appropriate commercial driver's license (CDL) and being medically unqualified to operate a CMV (FMCSR Parts 383 and 391).
4. **Controlled Substances or Alcohol:** Operation of CMVs by drivers who are impaired due to alcohol, illegal drugs, and misuse of prescription, or over-the-counter medications. Examples of violations include the use or possession of controlled substances or alcohol (FMCSR Parts 382 and 392).
5. **Vehicle Maintenance:** Failure to properly maintain a CMV. Examples of violations include brakes, lights, and other mechanical defects, and failure to make required repairs (FMCSR Parts 393 and 396).
6. **Cargo-Related Failures:** Failure to properly prevent shifting loads, spilled or dropped cargo, overloading, and unsafe handling of hazardous materials on a CMV. Examples of violations include improper load securement, cargo retention, and hazardous material handling (FMCSR Parts 392, 393, 397, and hazardous material violations).
7. **Crash Indicator:** Histories or patterns of high crash involvement, including frequency and severity. It is based on information from state-reported crashes.

A carrier's measurement for each BASIC depends on the following:

- the number of adverse safety events (violations related to that BASIC or crashes)
- the severity of violations or crashes
- when the adverse safety events occurred (more recent events are weighted more heavily)

After a measurement is determined, the carrier is then placed in a peer group (e.g., other carriers with a similar number of inspections). Percentiles from 0 to 100 are then determined by comparing the BASIC measurement of the carrier to the measurements of other carriers in the peer group. A percentile of 100 indicates the worst performance.

TABLE 1

Fleet Loss Run (Policy Effective Date: 5/15/2010 to 5/14/2011)

Claim Number	Date of Loss	Claimant Name	Claim Status Description	Accident Narrative	Paid Total	Reserved Total	Net Incurred Total
166123	09/01/2011	S. Jones	Closed	IV was rear ended by CV	$2235.46	$0.00	$98.00
166124	05/01/2011	J. Smith	Closed	Insured was driving north on Rt. 219 when tire blew	$2834.86	$0.00	$2834.86
166125	04/22/2011	F. Washington	Closed	Claimant vehicle hit IV at driver side doors	$1587.95	$0.00	$1587.95
166126	09/05/2011	A. Kennedy	Closed	IV was rear- ended by CV	$0.00	$0.00	$0.00
166127	05/05/2011	R. Jefferson	Closed	Insured was driving on Rt.19 when vehicle struck a deer	$4234.36	$0.00	$4293.36
TOTAL					$10,892.63	$0.00	$8814.17

Note: IV indicates insured vehicle, CV indicates claimant vehicle or the vehicle of others.

NHTSA ISSUES FINAL RULE ON REAR VISIBILITY TECHNOLOGY

Each year in the U.S., an average of 210 fatalities and 15,000 injuries are caused by vehicles striking individuals while the vehicle is in reverse. To help reduce these incidents, the NHTSA has issued a final rule requiring rear visibility technology in all new vehicles weighing less than 10,000 lbs. by May 2018. Affected vehicles will include small buses and trucks.

Under the rule, every vehicle must be equipped with rear visibility technology that expands the drivers' field of view to include 10 × 20-ft zone directly behind the vehicle. Other system requirements of the rule include specifications regarding image size, response time, durability and deactivation (NSC 2014).

Hopefully, this requirement will be expanded to larger vehicles in the future.

Additional Loss-Source Information for the Fleet Safety Professional

Fleet safety professionals have many potential loss sources at their disposal. Insurance carriers and their brokers and agents regularly produce and provide loss runs to assist in the analysis process. A loss run is a historical report of crash/incident information that has been given to an insurance carrier. A typical loss run will include, but not be limited to, the following:

1. date of the incident
2. driver/employee name
3. a brief description of the incident (e.g., "backing" or "struck fixed object")
4. location of the incident
5. anticipated cost or dollars reserved for future costs
6. costs to date

The loss run in Table 1 provides only an overview of needed information—the information it contains is limited by the input data and the ability of the software used to assemble and present the information. A fleet safety professional will need additional information and data in order to determine preventability. One of the goals of a successful fleet safety program is to propose appropriate countermeasures to minimize the possibility of a recurrence.

Exposures and Controls of the "Grey Fleet"

The *grey fleet* is a reflection of business miles traveled by employees using their own vehicles. Sales and service are two categories of employment most frequently associated with this group. These employees are typically paid a fixed mileage allowance for business purposes to cover the cost of operating their own car or truck. The employer has the advantage of minimizing the costs associated with purchasing or leasing a vehicle for this use, but not all costs of risk are eliminated.

While there is very limited data regarding the cost of incidents related to this business risk, the fact that employees are driving on company business presents both liability and worker's compensation exposures that may be significant.

In order to manage this aspect of the business risk, the fleet safety manager should include the following controls at a minimum:

- A copy of the valid insurance certificate should be obtained, including coverage for business use.
- A copy of the employee's driver's license should be obtained.
- A signed declaration should be obtained that the vehicle is fully serviced and maintained to the manufacturer's standards.

The same safety training provided to operators of company-owned vehicles should be mandated for these drivers. There are many appropriate defensive driving courses that are available for this purpose (Businesslink n.d.).

DIRECT AND INDIRECT COSTS OF ACCIDENTS

The image of an iceberg has been used by safety professionals to depict the direct and indirect costs of accidents. The direct costs are easily visible, similar to the section of an iceberg above the water. The indirect costs are buried below the surface of the water. The OSHA $afety Pays eTool discusses the cost of workplace injuries and illnesses in terms of the iceberg model (OSHA 1996).

"Accidents are more expensive than many of us realize. Why? Because there lots of hidden costs. Some are obvious—your workers' compensation claims cover medical and indemnity (lost wages) for an injured or ill worker. These are the direct costs of accidents. But what about the costs to train and compensate a replacement worker, repair damaged property, investigate the accident, and implement corrective action? Even less apparent are the costs related to schedule delays, added administrative time, lower morale, increased absenteeism, and poorer customer relations. These are the indirect costs and the bulk of the iceberg. Studies show that the ratio of indirect costs to direct costs varies widely, from a high of twenty-to-one to a low of one-to-one. We've taken a conservative approach that says that the lower the direct costs of an accident, the higher the ratio of indirect to direct costs" (OSHA 1996).

A worksheet is provided so that fleet safety professionals can determine the direct and indirect costs of accidents (see Figure 2). This worksheet also provides information that can determine the impact of injuries and illnesses on profitability.

These costs, in the context of this chapter, apply to employees of a fleet operator, including drivers, mechanics, sales personnel, administrative personnel, and management. The Federal Motor Carrier Safety Administration's (FMCSA) Accident Cost Table (see Figure 2 and Table 2) shows revenue dollars required to pay for different amounts of costs of accidents from a fleet's standpoint. Table 2 includes the following accident costs that could be considered in relation to a crash (FMCSA 2006).

Direct and Indirect Costs

Direct costs include:

- repair of cargo damage
- repair of vehicle damage
- medical treatment
- loss of revenue
- administrative
- police report
- possible effect on the cost of insurance
- possible effect on the cost of Workers' Compensation Insurance
- towing
- storage of damaged vehicles

Indirect costs include:

- revenue from clients or customers
- revenue from sales
- meetings missed
- salaries (wages) paid to employees in the accident
- lost time at work
- cost to hire and train replacement employees
- supervisor's time
- loss of personal property
- replacement vehicle rental
- damaged equipment downtime

WORKSHEET
How to Estimate the Impact of Accidents on Profits and Sales

Use this worksheet to determine costs of injuries and illnesses and their impact on business operations.

DIRECT COST

To calculate the direct cost, enter the following information:

- Total value of the insurance claim (medical costs and indemnity payments) for the injury or illness $________

INDIRECT COST

To calculate the indirect cost of this injury or illness, multiply the direct cost by a cost multiplier. The cost multiplier to use depends on the size of the direct cost.

If your direct cost is:	Use this cost multiplier:
\$0–\$2999	4.8
\$3000–\$4999	1.6
\$5000–\$9,999	1.2
\$10,000 or more	1.1

- Direct Cost × Cost Multiplier = Indirect Cost
\$______ ______ = \$______

TOTAL COST

- Direct Cost + Indirect Cost = Total Cost
\$______ \$______ = \$______

FIGURE 2. How to estimate the impact of accidents on profits and sales (*Source:* OSHA 1996)

TABLE 2

Accident Cost Table

THIS TABLE SHOWS THE DOLLARS OF REVENUE REQUIRED TO PAY FOR DIFFERENT AMOUNTS OF COSTS FOR ACCIDENTS

It is necessary for a motor carrier to generate an additional \$1,250,000 revenue to pay the cost of a \$25,000 accident, assuming an average profit of 2%. The amount of revenue required to pay for losses will vary with the profit margin.

Yearly Accident Costs	Profit Margin				
	1%	2%	3%	4%	5%
\$1,000	100,000	50,000	33,000	25,000	20,000
5,000	500,000	250,000	167,000	125,000	100,000
10,000	1,000,000	500,000	333,000	250,000	200,000
25,000	2,500,000	1,250,000	833,000	625,000	500,000
50,000	5,000,000	2,500,000	1,667,000	1,250,000	1,000,000
100,000	10,000,000	5,000,000			
150,000		7,500,000	3,333,000	2,500,000	2,000,000
200,000	15,000,000	10,000,000			
			5,000,000	3,750,000	3,000,000
	20,000,000				
			6,666,000	5,000,000	4,000,000

REVENUE REQUIRED TO COVER LOSSES

(*Source*: FMSCA 2006)

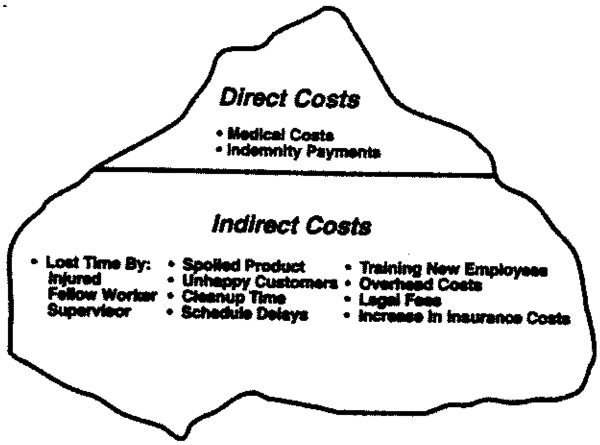


FIGURE 3. Direct/indirect costs iceberg (*Source:* OSHA 1996)

- accelerated depreciation of equipment
- accident reporting
- medical costs paid by the company
- poor public relations/publicity
- increased public relations costs
- government agency costs

If this worksheet is applied to fleet accidents and coupled with the Revenue Required to Pay for an accident chart, it is apparent that even a $5000 accident can impact profitability.

For example, an accident involving $5000 in direct costs would result in $6000 in indirect costs, so the total cost would be $11,000. If a company operates at a 4 percent profit margin, it would need to generate over $250,000 in additional sales to cover the cost of this accident/incident. This example assumes a $5000 deductible by the carrier on a per accident/incident basis. The *iceberg* in Figure 3 "demonstrates the relationship between direct and indirect costs of accidents" (OSHA 1996) and the Accident Cost Table (Table 2) sets out the revenue necessary to pay for accident losses. According to the FMCSA average, indirect costs exceed direct costs by a four-to-one ratio.

Accident Register

An additional source of information for fleet safety professionals conducting analyses of incidents and crashes is the Accident Register. Part 390.15 of the Federal Motor Carrier Safety Regulations (FMCSR) is reproduced in the sidebar.

A sample accident register is shown in Figures 4A and B.

Fleet safety professionals should use all of the tools detailed in this chapter to conduct regular analyses of their fleets' losses. Detailed analyses will provide opportunities for continuous improvement of safety efforts. An accident register can be used to determine trends, which in turn will provide information for future needs and initiatives for driver selection, equipment, safety training, and related information.

National Safety Council®

MOTOR TRANSPORTATION

ACCIDENT REGISTER

PERIOD COVERED ________ TO ________

ACCIDENT NUMBER ________ TO ________

COMPANY ________________

LOCATION ________________

NATIONAL FLEET SAFETY CONTEST

KEY CODE NO. ____

DIVISION OF CONTEST ________

	ACCIDENT DATE	ACCIDENT NUMBER	DRIVER'S NAME	DRIVER'S HOME TERMINAL	VEHICLE NUMBER	ACCIDENT TYPE	SHOW NEAREST CITY & STATE
1							
2							
3							
4							
5							

FIGURE 4A. Sample accident register (*Source:* NSC 1996)

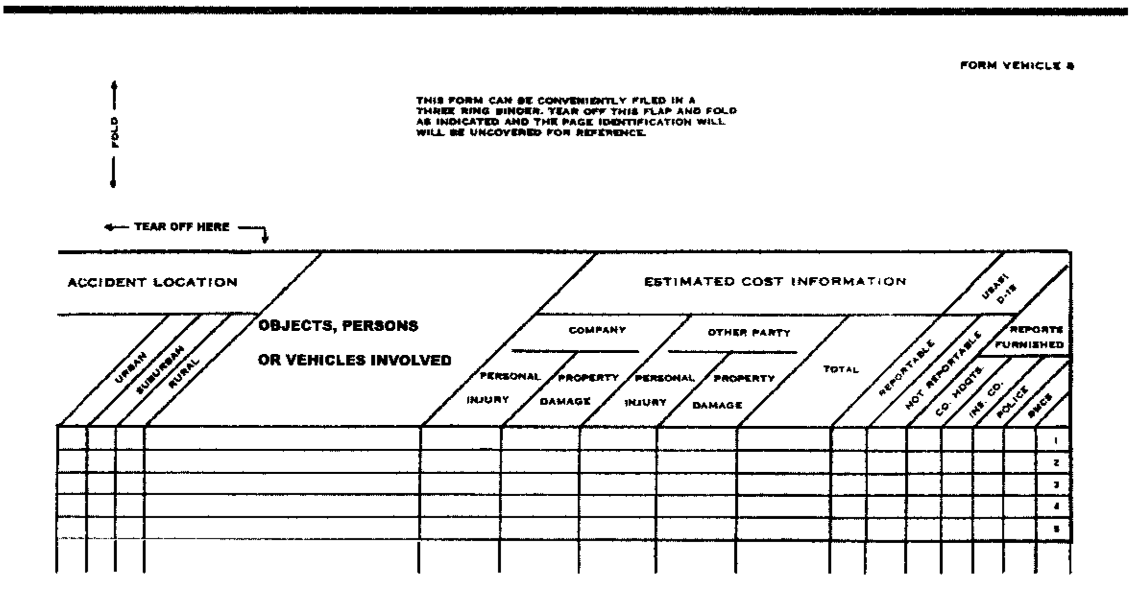


FIGURE 4B. Sample accident register (*Source:* NSC 1996)

Cost-Benefit Analysis

An effective fleet safety program can produce benefits to the employer, employee/driver, and the customer or client. Well-managed fleets also benefit the community or communities in which they operate.

The National Safety Council (NSC 1996) indicates that some benefits of an effective safety program are:

- reduced costs of operations
- reduced insurance premiums and related costs
- improved customer satisfaction
- lower employee turnover
- improved employee morale

While all of these benefits would be considered logical to anyone operating a fleet, the safety program alone may not achieve them. It is essential that all drivers be aware that the safe operation of vehicles is very important. The standard explains that organizations should periodically evaluate driver performance.

Many types of safety initiatives may have an impact on a company's cost of operations. One is direct observation and feedback from the general public regarding vehicles that are clearly identified with either a company phone number or a commercial safety hotline call-in program. Anyone who drives has probably seen decals on commercial vehicles asking "How is my driving?" along with a vehicle identification number and toll-free phone number. Two companies that provide this early warning service indicate that insurance companies have studied the financial impact of these programs. The Safety Alert Network states that clients have reported a vehicular accident-frequency reduction in excess of 40 percent when using the program (Safety Alert 2006).

Safety Alert charges a one-time fee of $3.95 to place a decal on a trailer plus an annual per-vehicle charge based on the number of vehicles. The company provides this estimated benefits information:

frequency rate of accidents × million miles driven
= number of accidents (1)

number of fleet accidents × $9000/accident
= cost of accidents (2)

cost of accidents × 0.10 (a conservative reduction
in accident savings) = minimum net savings (3)

For example, if a fleet operates 50 vehicles and 100 trailers, the cost of the program is estimated at $5000 for the first year, and $1400 for subsequent years (50 vehicles at approximately $20 per vehicle and 100 trailers at $4 per trailer).

According to the ROI calculator provided on the Safety Alert Network Web site, the ANSI vehicular accident rate for over-the-road vehicles in 1995 was 2.0 per million miles. If the fleet in our example drives 5 million miles per year, the savings would be estimated as follows:

$2.0 \times 5 = 10$ accidents

$10 \times \$9000 = \$90{,}000$ in accident costs

$\$90{,}000 \times 0.10 = \$9000$ in avoided accident costs

$9000 in avoided accident costs – $5000 cost
of service = $4000 net savings (4)

This is a very conservative estimate.

FMCSR, PART 390.15

"Assistance in investigations and special studies.

"(a) A motor carrier must make all records and information pertaining to an accident available to an authorized representative or special agent of the Federal Motor Carrier Safety Administration, an authorized State or local enforcement agency representative, or authorized third party representative, upon request or as part of any investigation within such time as the request or investigation may specify. A motor carrier shall give an authorized representative all reasonable assistance in the investigation of any accident including providing a full, true, and correct response to any question of the inquiry.

"(b) For accidents that occur after April 29, 2003, a motor carrier must maintain an accident register for three years after the date of each accident. For accidents that occurred on or prior to April 29, 2003, motor carriers must maintain an accident register for a period of one year after the date of each accident. Information placed in the accident register must contain at least the following:

"(b)(1) A list of accidents as defined at 390.5 of the chapter containing, for each accident:

"(b)(1)(i) Date of accident.

"(b)(1) (ii) City or town, or most near, where the accident occurred and the State where the accident occurred.

"(b)(1)(iii) Driver name.

"(b)(1)(iv) Number of injuries.

"(b)(1)(v) Number of fatalities.

"(b)(1)(vi) Whether hazardous materials, other than fuel spilled from the fuel tanks of motor vehicle involved in the accident, were released.

"(b)(2) Copies of all accident reports required by State or other governmental entities or insurers."

Paul Farrell of Safety First, which also operates a hotline program, has conducted numerous studies on the benefits of these monitoring programs and has determined that savings can be as high as 20 percent of the cost of accidents.

While Safety Alert and Safety First are only two examples of safety initiatives that produce encouraging results, the use of technology is changing daily and will ultimately be used to improve safe driving habits and reduce risky behaviors. Additional studies are needed to determine the impact of safety training and initiatives similar to those noted above.

Budgeting for Fleet Safety

The fleet safety professional or the person responsible for fleet safety in a company should consider the cost of three major components of the safety program in order not only to ensure compliance but also to operate in a safe and efficient manner. These cost components are:

1. record keeping
2. fleet safety training
3. fleet maintenance

In 2008, ORC Worldwide (now Mercer) engaged eighteen occupational health, safety, and environmental professionals and others to provide a comprehensive look at investment decisions and to answer important questions, such as:

- What health and safety or environmental investments should we make?
- When should we make a particular investment?
- Which health and safety of health investments create the greatest value to the organization?
- How do we compare an operational investment decision to an OS&H decision?
- How do we know we are doing the "right things" in the "right way?"
- To which projects should we allocate our human resources?
- How can we demonstrate the business value of our organization?

The return on the health, safety, and environmental investment process and software tools facilitates and encourages a team approach and calculates financial metrics in a common language. This type of tool, along with others referred to in this section, provides the fleet safety manager with the information to make informed decisions for the control and minimization of risk.

Record Keeping

The ANSI/ASSE Standard Z15.1-2012, *Safe Practices for Motor Vehicle Operations*, states, "Organizations shall maintain documentation of the qualifications and driving records of drivers." The data or documents needed for this aspect of fleet safety are noted in the section below.

Either a specific budget for an outside consultant should be established for these compliance efforts or the fleet safety professional should allow ample time in his or her regular work activities to complete these review and administrative activities.

From a driver perspective, the driver file is a critical component for compliance. A small fleet can be audited just as readily as a large one. The driver file and its related documents are a significant aspect of any compliance review. The Federal Motor Carrier Safety Regulations are found in the Code of Federal Regulations (49 CFR) 300–399.

The documents contained in each driver's file must include

- employment application
- current medical certificate
- DOT medical waiver, if applicable
- certificate of road test or equivalent, such as a CDL
- past employment verifications
- motor vehicle record
- annual review of driving record
- annual list of driver violations
- other documents, such as safety training records, pertinent to the driver's ability to operate a commercial motor vehicle

In accordance with 49 CFR 396.3(b), the vehicle maintenance file must contain

- an identification of the vehicle
- a method or document to indicate the nature and due dates of inspections and maintenance
- a record of inspections, repairs, and maintenance, indicating their date and nature or type
- a record of tests conducted on push-out windows, emergency doors, and emergency-door marking lights on buses

In addition to the costs associated with the review and maintenance of these records, fleet safety professionals are responsible for and may incur costs for keeping the written programs, policies, and procedures for the overall safety process current. This could require attendance at seminars or training sessions in order to stay up to date on changes in the regulations. Many organizations offer such seminars throughout the United States.

Fleet Safety Training

The Z15 standard also states, "Organizations shall establish a driver training program. The driver training program shall address requirements for new drivers, continuing education of existing drivers, and instances where remedial training shall be required" (ANSI/ASSE 2012).

The standard further states, "The training should include both classroom and behind-the-wheel training" (ANSI/ASSE 2012). The following topics should be considered for the training sessions:

- defensive driving
- substance abuse
- distracted driving (e.g., cell-phone use)
- aggressive driving (e.g., tailgating)
- vehicle inspection
- commodity-specific training (e.g., hazardous materials, material handling, cargo securement)
- safety regulations
- security procedures
- emergency equipment
- post-incident procedures
- vehicle inspection/maintenance

There are numerous software solutions for the fleet safety manager to consider to manage the data associated with the record-keeping requirements and safety training, as well as other aspects of the operation of a fleet of vehicles. FleetMentor from J. J. Keller, an online toolbox and advisor to assist the fleet safety manager with the myriad of tasks that impact fleet safety, provides tools and resources that include the following (J. J. Keller, Inc. n.d.):

- accident register
- best practices for fleet operations
- cargo securement
- driver and supervisor training
- motor-carrier safety audits
- online safety training
- PM service schedule
- roadside inspection tracking
- repair and maintenance costs
- scoring MVRs

These tools follow the CSA requirements and provide additional resources to adequately manage the fleet's needs. The fleet safety manager is encouraged to review the software products available from J. J. Keller and others.

Evaluating the Risks of Driving

In September 2003, the Health and Safety Executive (HSE) published a pamphlet entitled *Driving at Work: Managing Work Related Road Safety*. A significant portion of this publication is devoted to assessing the risks involved with road safety, including but not limited to the driver, training, vehicles, and the journey itself. The pamphlet suggests that working through a section on evaluating these risks will answer many questions that the fleet safety manager may not have considered. The "Training"

WHITE PAPER SHOWS TRUCK DRIVERS' SAFETY COMPLIANCE KNOWLEDGE LACKING

A white paper from American Transportation Research Institute (ATRI), "Compliance, Safety and Accountability (CSA): Assessing the New Safety Measurement System and Its Implications-2013 Update" shows that truck drivers do not have a clear understanding of CSA, after 3 years of its implementation. According to the Federal Motor Safety Administration, the CSA program was implemented in 2010 "to provide a better view into how well large commercial motor vehicle carriers and drivers are complying with safety rules, and to intervene earlier with those who are not."

The recent report includes 7,800 responses of drivers who were analyzed over the three year period. ATRI reports that the drivers on average, responded to the CSA knowledge test with 42.4% accuracy, which suggests that drivers still do not have a clear understanding of CSA. Despite this lack of knowledge, ATRI also reports carrier provided training has increased since 2011 and drivers job security concerns related to CSA have decreased by about 10% over the three-year period (ATRI 2013). To obtain a copy of the white paper, go to http://atri-online.org.

section asks, "Are you satisfied that your drivers are properly trained?" The following questions help in the risk assessment:

- Do you evaluate whether those who drive at work require additional training to carry out their duties safely?
- Do you provide induction training for drivers?
- Do you arrange for drivers to be trained, giving priority to those at higher risk (i.e., those with high annual mileage, poor crash records, or young drivers)?
- Do drivers know how to correctly adjust safety equipment (i.e., seat belts and head restraints)?
- Do drivers know how to use antilock brakes properly?
- Do drivers know how to check washer-fluid levels before starting a journey?
- Do drivers know how to ensure safe load distribution (i.e., when undertaking multidrop operations)?
- Do drivers know what actions to take to ensure their own safety following the breakdown of a vehicle?
- Do you need to provide a handbook for drivers, giving advice and information on road safety?
- Are drivers aware of the dangers of fatigue?
- Do they know what to do if they feel sleepy?
- Are drivers fully aware of the height of their vehicle, both laden and empty?

The final question of the assessment is appropriate and a great lead-in to the next section of this chapter, "Has money been budgeted for training? To be effective training needs should be periodically assessed, including the requirements for refresher training" (HSE 2003).

The Cost of Driver Training

Several types of safety or driver training sessions are used by fleet safety professionals.

Initial Training

When new employees are hired, a supervisor or a fleet safety professional should communicate the company's safety expectations. The time for this training will depend on the nature of the vehicle to be operated, the experience of the employees, and the organization's level of sophistication with regard to safety. *Many companies find that the more time they spend on initial training, the more likely it is that new hires realize the importance of safety.* The cost of initial training is usually part of the cost of the new-hire orientation process.

Calculating the cost for each hour of orientation should include:

- employee's hourly rate and benefits
- trainer's hourly rate and benefits
- clerical and administration time (hourly rate and benefits)

For example, *The Occupational Outlook Handbook* (BLS 2014) states that in 2012 the median hourly pay for heavy-truck and tractor-trailer drivers was $18.37. If a trainer earns $50,000 per year ($25 per hour) and an administrative employee earns $25,000 per year ($12.50 per hour) and benefits for each category cost approximately 30 percent of earnings, a single hour of orientation would cost

Driver	$18.37 plus $5.51 = $23.20
Trainer	$25.00 plus $15.60 = $40.60
Administrative employee	$12.50 + $3.75 = $16.25
Total cost:	$80.05 for one hour of orientation

Annual Training

Due to the nature of fleet operations, many companies conduct annual safety meetings lasting from as little as one hour to an entire day. In addition to updating drivers on policy or equipment changes, this is an opportunity to review the importance of safe driving techniques and safe behaviors. Often guest speakers are invited to participate in the sessions to provide a new or fresh perspective on safety. This type of meeting/training (if held annually) may also include a *safety awards* recognition program in which drivers are rewarded for years of driving without a preventable accident. The American Trucking Association (ATA) published a study highlighting exceptional approaches to safety management by some of the country's safest carriers, including some that won safety awards. The study notes that the average spent on safety for all surveyed carriers was $1060 per powered unit, but for the award-winning carriers the average was $2500 per powered unit. These expenditures included costs of driver training, compliance, safety awards, and safety meetings (ATA 1999).

- The cost of safety training includes wages and benefits paid to drivers while they are attending training sessions as well as the cost of speakers, video equipment and facilities, refreshments and meals, and rewards (ATA 1999).

Remedial Training

Remedial training may be necessary if employees have safety violations or a certain number of *chargeable* or preventable accidents during a specified time period. During this training, an effort is made to modify employees' behavior or to determine whether they have special needs that should be addressed. The cost of remedial training is an hourly rate for the driver plus the cost of the trainer's time (ATA 1999).

Ongoing Training

Computers have made this type of training readily available and affordable. A search of the Internet using the phrase "fleet safety training" reveals literally thousands of resources, many of which offer online training. The cost of the training depends on several factors, including the number of drivers to be trained and the number of training modules chosen.

Is there a cost benefit for this type of training? AlertDriving provides an example of the return on investment (ROI) on its Web site with an ROI calculation scenario showing that if eight training modules are presented to 125 drivers, the cost of the program per driver is $43. Several companies that have used the training have reduced their accidents per million miles by an average of 20 percent with a potential savings of $145,000 each. The ROI is over 30 percent per carrier (AlertDriving 2006).

Boorman notes that Occupational Health Services, which operated 48 vehicles in 1994, reduced its average net cost per claim by £1500 over four years and reduced its overall cost by £65,000 in the same time period. The training consisted of a three-pronged approach: (1) raising driver awareness, (2) identifying higher-risk drivers, and (3) providing advanced driver training and providing targeted support to drivers after an incident. The cost per driver was estimated at £125 (Boorman 1999).

Fleet safety professionals are encouraged to find safety training that meets the needs of the fleet and should evaluate the ROI over a three- to four-year period.

The many aspects of ongoing training will also be discussed in the "Best Practices" chapter.

Cost of Vehicle Maintenance

The Federal Motor Carrier Safety Regulations, Part 396.3, require motor carriers to "systematically inspect, repair, and maintain, or cause to be systematically inspected, repaired, and maintained all motor vehicles" under their control (FMCSA 2008). It is considered good business practice to comply with these regulations. In fact, Standard Z15.1 states, "The purpose of the Standard is to provide organizations with a document for the development of policies, procedures, and management processes to control risks associated with the operations of motor vehicles. It is not intended to be a mandate for its use; it has been developed to assist organizations in defining and developing an effective risk management program for their vehicle operations" (ANSI/ASSE 2012).

In Section 6, "Vehicles," Standard Z15.1 states, "Organizations shall institute formal maintenance procedures and record-keeping procedures that meet or exceed the vehicle manufacturer's recommendations, giving consideration to the operating environment" (ANSI/ASSE 2012). The standard also addresses scheduled maintenance, repairs, qualified automotive service personnel, automotive service facilities, and vehicle replacement:

- ***Scheduled Maintenance.*** All vehicles shall be maintained by qualified automotive service technicians at regular intervals based on miles driven, hours of operation, and/or calendar time.
- ***Repairs.*** When defects are reported, the vehicle shall be repaired by a qualified automotive service technician. Safety-related defects shall be repaired before the vehicle is placed back in service, with appropriate records maintained.

- ***Qualified Automotive Service Personnel.*** All personnel performing maintenance, repair, modifications, or inspections shall possess the requisite skills and be qualified through experience and training.
- ***Automotive Service Facilities.*** Organizations performing their own vehicle maintenance shall have appropriate facilities and automotive service equipment to perform the required tasks. When maintenance is performed by vendors, the organization shall assess each vendor's ability to adequately perform the required service.
- ***Vehicle Replacement.*** Organization-operated vehicles shall be replaced according to formal procedures. Factors that affect the need for replacement include total mileage, maintenance cost, condition, operating requirements, operating environment, hours of service, and safety. Additional information below regarding life-cycle costing notes similar considerations and methods of determining these criteria (ANSI/ASSE 2012).

All of the above maintenance considerations are costly to an organization. *Vehicle Maintenance: A Comprehensive Guide to Improved Operations & Compliance* (J. J. Keller and Associates 2001) provides some insight on the expense associated with the maintenance aspect of fleet operations. The section entitled "Organizing Maintenance Programs" emphasizes the importance of tracking costs, stating:

> Operating costs are all the expenses directly related to running a vehicle on the road. Generally, driver expenses amount to about 50 percent or even more of the total costs of operating a vehicle. Vehicle expenses and indirect expenses (clerical staff, office supplies, etc.) make up the rest. Driver expenses include wages and benefits, but for the fleet that employs its drivers, rather than leases them, all employer-paid items must be included.

The guide notes that vehicle expenses are the second major category of costs. They include fixed costs: interest, depreciation, licenses, taxes (federal and state), permits, and insurance (vehicle and cargo) and variable costs: maintenance (labor and parts), fuel, oil, tires, tolls, and other miscellaneous road expenses. While variable costs are difficult to predict, they can be controlled (J. J. Keller and Associates 2001).

The cost per mile is the total dollar amount that it takes to run one truck for one mile. The guide states that cost per mile is the best and most convenient measure of trucking costs and is an easy indicator to use for comparison between vehicles (J. J. Keller and Associates 2001).

TABLE 3

Cost Per Mile

Labor Costs	Nonlabor Costs
Driver—$0.445	Fuel—$0.138
Repair Wages—$0.049	Fuel Taxes—$0.059
Supervision—$0.025	Highway Taxes—$0.028
Other Labor—$0.013	Repair/Parts—$0.059
Fringes—$0.153	Tires/Tubes—$0.026
	Insurance—$0.032
	Depreciation—$0.083
	Other—$0.052
TOTAL—$0.684	TOTAL—$0.476

(*Source*: J. J. Keller and Associates 2001)

In statistics developed by Transportation Services of Fredericksburg, Virginia, (cited in J. J. Keller and Associates 2001, 5) from reports of 46 large general freight carriers, all with revenues above $20 million, the cost of operating a truck over the road was approximately $1.16 per mile. Of that total, 47.6 cents was spent on nonlabor costs and 68.4 cents was spent on labor costs. The study included primarily unionized drivers; this cost could be higher than in nonunion operations. The breakdown is found in Table 3.

Although this study was completed in 1990, it is a good model for determining cost per mile. These formulas can be used to determine the cost per mile and revenue per mile.

$$\text{total cost/total miles} = \text{cost per mile} \tag{5}$$

$$\text{total revenue/total miles} = \text{revenue per mile} \tag{6}$$

Fleet safety professionals are encouraged to use this data to determine areas where operating costs can be controlled using good risk-management practices.

Life-Cycle Costing

The decision to replace a truck should be based on life-cycle costing (J. J. Keller and Associates 2001). Life-cycle costing can also indicate the need for component replacements. Ideally, fleets replace vehicles the moment it costs more to keep them than to replace them. The guide suggests that the following vehicle records are important in determining when this moment occurs:

- the truck's initial cost and component specifications (which become the vehicle's history)
- the fuel/oil/lube/filter data (from purchase records)
- the vehicle utilization data (from driver reports and mileage logs)
- the maintenance data (from repair orders)

NIOSH OUTLINES STRATEGY FOR REDUCING MOTOR VEHICLE-RELATED WORKER DEATH

In May 2014, the National Institute for Occupational Safety and Health (NIOSH) unveiled a plan aimed at reducing work related deaths caused by motor vehicle crashes, the leading cause of worker fatalities. The Institute's Center for Motor Vehicle Safety (CMVS) defined areas of research and prevention initiatives and set performance measurements in the 2014-2018 plan. Five specific goals of the plan were identified by the CMVS:

1. Advance understanding of the risk factors associated with work-related crashes.
2. Reduce the incidence and severity of work-related crashes through engineering and technology-based safety interventions.
3. Reduce the incidence and severity of work-related crashes through evidence-based road safety management policies.
4. Reduce work-related crashes and injuries through national and international research collaborations.
5. Enhance availability of guidance and products that help prevent work-related crashes.

John Howard, NIOSH Director said the "millions of workers in the United States are exposed to motor vehicle traffic, as vehicle operators, passengers, or pedestrians." In the Foreword of the plan, Howard also said, "the new strategic plan gives the center the flexibility to address emerging issues along with longstanding safety concerns."

The responsibility of reducing the number of motor vehicle-related worker deaths is shared by employers, workers, policymakers, vehicle manufacturers, and research alike, according to Howard (NIOSH 2014).

In the opinion of the author, this important work is long overdue.

A tracking system can aid in determining the cost of operating a fleet and is a key component of vehicle-replacement decision making. A computerized tracking system also simplifies record keeping for fleet management.

A search of the Internet for "Fleet Maintenance" reveals numerous computerized tracking systems that fleet safety managers can use to determine fixed and variable costs. These systems assist in determining the cost of operating an individual vehicle in the fleet as well as the cost of operating the overall fleet. As noted in the Z15 standard, maintenance procedures and record-keeping procedures must meet or exceed the manufacturer's recommendations (ANSI/ASSE 2012).

Tracking systems provide data necessary for deciding when vehicles should be replaced. The Z15 standard states that "organization-operated vehicles shall be replaced upon formal procedures" (ANSI/ ASSE 2012). The standard explains that the factors involved in a decision to replace a vehicle include total mileage, maintenance costs, vehicle condition, operational requirements, operating environment, its hours of service, and vehicle safety (ANSI/ASSE 2012).

For a discussion of software for tracking FMCSA CSA requirements, see the end of the section on record keeping earlier in this chapter.

Conclusion

Fleet safety will continue to evolve with the advent of improved training methods, in-cab monitoring, driver professionalism, and maintenance practices. The primary responsibility for these improvements lies in the hands and wallets of the owners and managers of fleets and motor carriers. Without management commitment to safety and adequate resources, little progress will occur. Fleet safety professionals must be creative and innovative in their day-to-day activities in order to lead a safety process that will minimize crashes and prevent injuries.

There is still a need for additional research into this topic. A study of both regulated and nonregulated fleets should be conducted with the conclusions presented as a business case for driver training in all organizations that place drivers at risk on our nation's roads.

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ADDITIONAL READING

CONTROLLING FLEET LIABILITY RISKS THAT COULD DRIVE YOU OUT OF BUSINESS*

Timothy J. Batz, CSP, ARM, CRIS
IMA, Inc.
Denver, CO

Introduction

According to the National Highway Traffic Administration, in 2011 there were 32,367 motor vehicle fatalities in the United States. The Center for Disease Control, in 2011, calculated that the cost of fatal crashes topped $41 Billion. In the 1970's, according to the National Institute of Health, alcohol was a factor in 60% of traffic deaths. In recent years, that percentage has dropped to 32%, according to the Center for Disease Control.

Drivers who use hand-held devices are four times more likely to get into crashes serious enough to injure themselves, according to study by Monash University in Australia. According to the Virginia Tech Transportation Institute (VTTI), text messaging while driving creates a crash risk 23 times worse than driving while not distracted. You may also be surprised to know that a hands-free cell phone use is **not** substantially safer than hand-held use, also according to the VTTI. Many states have enacted laws requiring that drivers must use a hands-free device (Bluetooth) if they choose to talk on the phone while driving. Does that make sense? Finally, a study by Carnegie Mellon University showed that engaging in a secondary task, such as talking on a cell phone, reduces the amount of brain activity associated with driving by 37%. These studies are instructive and we, as safety professionals, need to be aware of the hazards of distracted driving and what we can do to manage them.

What's the Big Deal? We Have Insurance

To answer that question, one needs to understand some basics about our legal system. It's been said of our legal system that it's the worst there is…except for all the rest. One characteristic of our legal system is that it offers access for those who feel that they have been wronged. If a person has no resources to hire a lawyer, there are plaintiffs' lawyers who will take the case on a contingency basis; that is, the attorney's compensation is contingent upon an award or settlement in favor of the plaintiff.

In our system of justice, a person (plaintiff) can bring a legal action against another if they feel the person (defendant) was negligent and that negligence caused them harm.

According to www.legal-dictionary.com, In order to establish negligence as a cause of action under the law of torts, a plaintiff must prove that the defendant had a duty to the plaintiff, the defendant breached that duty by failing to conform to the required standard of conduct, the defendant's negligent conduct was the cause of the harm to the plaintiff, and the plaintiff was, in fact, harmed or damaged.

Is your organization doing what is reasonable? What is "reasonable?" According to www.legal-dictionary.com, the term "reasonable" is a generic and relative one and applies to that which is appropriate for a particular situation. Look again at the definition of negligence.

The standard your company will be held to is what a "reasonable person do in similar circumstances."

Ask yourself if these statements sound reasonable:

- My employee has a driver's license, that's good enough.
- Checking employee driving records is too cumbersome.
- That person makes me a lot of money; I can't put restrictions on him/her.
- I took away the company car and now she drives her own car for business.
- I checked the employee's driving record when he was hired many years ago.
- It's only one DUI, everybody makes mistakes.

These are excuses I commonly hear from businesses. How defensible are your company's acts or omissions? Are your acts/omissions reasonable? Do you have a written fleet safety program? Does your company check employee driving records periodically? If not, why not? You might find that your company is not acting reasonably.

For that matter, who defines "reasonable?" It can be a long and winding road, but juries often are the ones who determine if the defendant acted reasonably. Relying on "common sense" isn't a good idea: Go back to "what a reasonable person who do in similar circumstances."

From a liability standpoint, the good news is that business auto liability insurance is designed to respond to claims of negligence (including gross negligence). For example, if an employee is driving a vehicle for business and negligently injures another, the insurance policy is designed to respond to claims of bodily injury and property damage. That doesn't mean the claimant will be sent a check. It simply means that the policy will respond with your legal defense and pay damages that you're a legally obligated to pay for harm to another person or property.

Of course, with the insurance in place, insurance carriers would like to see some control exercised over which employees drive company vehicles or who drive their own vehicles on company business. An insurance carrier is in a contractual relationship with the policyholder to provide financial responsibility in the event the insured is legally liable. It is understandable that they would want some controls in place to minimize exposure to loss.

The criteria that most insurance carriers like to see include driver selection, such as a periodically checking an employee's driving record against a written criteria, driver safety training and written plan to implement safety procedures. You will also find that carriers are interested in those who drive their personal vehicles for business and expect the same criteria to be applied.

Why do carriers pay attention to employees who drive personal vehicles on company business? Because it's a source of loss.

When employees drive their own vehicles on company business, it is indeed an auto liability exposure for the business. Commonly, if the employee is involved in a crash while driving their own vehicle for a work, their personal automobile insurance will respond if they are legally liable.

But what happens if the employee doesn't have insurance or has very low limits of liability? The business auto liability carrier will likely respond to this legal liability, and that's why business auto liability carriers are interested in the control of this exposure.

Motor Vehicle Records (MVRs)

The value of checking a drivers motor vehicle record (MVR):

- Do you check motor vehicle records (MVRs) for drivers in your organization? If you run MVRs, at what point do you restrict n employee to drive on company business?
- Many organizations have realized the liability exposure of having employees driving vehicles and have chosen to implement a procedure that includes checking MVRs.
- If you do indeed check MVRs, what is a reasonable criterion?

Below are the minimum criteria that businesses should consider:

1. There have been no major violations within the past five years: Major violations are generally defined as convictions for:
   - DUI
   - reckless driving
   - commission of a felony while driving a motor vehicle
   - refusal to take an alcohol test
   - leaving scene of an accident
   - drag race or speed contest
   - eluding a police officer
   - speeding in excess of 25 mph over the posted limit
2. No more than three minor violations within the past three years. Minor violations are defined as convictions for:
   - speeding below 25 mph
   - failure to yield
   - failure to stop
   - any moving violation not considered major

So, what should a business do if drivers don't meet the criteria? The short answer is to not allow the employee to drive on company business, in a company car or in his/her own vehicle. Before you criticize the criteria as unrealistic, realize that legal liability is real and has consequences.

- Here's an actual case: Alicia Bustos was a passenger in the back seat of a Buick when her car was hit by a F150, whose driver was using a cell phone at the time of the crash, which left her severely injured and ventilator-dependent. Following the accident, she sued the driver of the Ford and the driver's employer. A Miami jury awarded Bustos and her husband $20.98 million; the lawsuit was later settled for $16.1 million. *Bustos v. Leive*, No. 01-13370 CA 30 (Miami-Dade Co., Fla., Cir.Ct.) Central to the case was the use of the cell phone while driving.

- The insured *was* a well servicing contractor. I use was in the past tense because the company is not in business any longer as a result of this incident. It had been raining heavily all day so the owner took the crew to a bar for some "team building." After several hours and multiple pitchers of beer, the crew departs in company vehicles. Two employees race side by side on a two-lane road and collide with a vehicle carrying four teenage girls. The crash resulted in three fatalities and one severe brain injury. The auto liability insurance carrier paid policy limits and the court granted a very large punitive damage award.

These types of huge awards are unusual, but it makes the point that these types of losses can drive a company out of business. Insurance can pay for actual damages up to policy limits, but punitive damages are generally not insurable as a matter of public policy.

A Word about Technology

With technology moving at lightning speed, there a new products and services coming onto the market to help employers manage these exposures. Some products can be plugged into the diagnostic port under the vehicle's dashboard and give you very telling data about your drivers' habits, how many hard stops and starts he/she has in a given time period, and even the how much time is spent idling.

Other technologies will allow an employer to see an employees' motor vehicle record in real time, simply with the click of a button. Moreover, vehicles can be equipped with GPS tracking devices that will send a notification to the employer if it leaves a predetermined geographical area.

There is even a product recently available that will disable a phone while located in a moving vehicle. Technology solutions are readily available and at a relatively low cost.

What Businesses Can Do

How can you as a safety professional help minimize this exposure? Knowing that a one size fits all approach isn't likely to work, you should focus on making incremental progress over time.

The safety professional should also know that what is reasonable will change over time. A generation or two ago, if you were pulled over by the police for driving drunk, law enforcement might tell you to go straight home and sleep it off. Society's view of drunk driving has changed since then. Due to the efforts of organizations such as Mothers Against Drunk Driving (MADD), public health campaigns and state lawmaking, society now takes a much dimmer view of drunk driving. If you are stopped for drunk driving in today's world, you will likely be arrested, spend several hours in the company of law enforcement and lose your driver's license for a period of time.

How can we as safety professionals help?

- Have a written driver safety policy that includes motor vehicle record (MVR) criteria
- Evaluate all employees who will drive company or their own vehicles on company business and review their driving records periodically thereafter
- Formalize driver training
- Enforce disciplinary standards
- Have a distracted driving policy and address cell phone usage
- Require the use of seat belts.
- Know that there is an ANSI standard on the topic, (Z15.1), *Safe Practices for Motor Vehicle Operations*