Evaluation of Tractor and Grain Wagon Safety Marking at Selected Commercial Iowa Grain Elevators

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Abstract

The three categories of agents involved in the largest number of agricultural fatalities in Iowa are tractors, other farm machinery, and motor vehicles. All are involved during harvest as grain is transported on public roadways. Forty-eight percent of all motor vehicle collisions involving farm equipment in Iowa occur from October through December. Tractors and wagons delivering grain to six elevators during fall harvest were evaluated. Vocational agriculture student teams inspected for compliance with Iowa code and ASAE standards for lighting, marking, hitch, and ROPS safety equipment.

A majority of tractors complied with safety standards for: headlights, front amber flashing lights, slow moving vehicle (SMV) emblem, and roll over protection structure (ROPS). Tractors less than eight years old met Iowa code and ASAE safety standards for rear amber flashing lights and rear taillight. Tractors less than 15 years old were more likely to be equipped with ROPS (98%) than were tractors more than 15 years old (67%). Compliance with safety items other than ROPS did not significantly differ among tractor age groups. A majority of wagons at the elevators complied with ASAE safety standards for an SMV emblem and retainer on the hitch pin. Other wagon safety items all had lower compliance than all tractor safety items.

Keywords. Lighting, Hitch, ROPS, SMV emblem.

Agriculture has one of the highest death rates among industries in the United States. Excluding persons under 14 years of age, the National Safety Council (1995) estimated 26 deaths per 100,000 agricultural workers in 1994. Farm machinery and motor vehicles used for farm-related purposes are often involved in unintentional deaths. Tractors, machinery, and motor vehicles were the most frequently involved injury agents in unintentional occupational farm fatalities during 1992 in Iowa (Iowa Department of Public Health, 1993). Together they accounted for 64% of 83 recorded fatalities. Thirty-one percent of the agricultural injuries involving tractors, machinery, or motor vehicles occurred during October and November (Iowa Department of Public Health, 1993).

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The National Safety Council (1993) estimated that nationally 8,000 motor-vehicle accidents during 1992 involved farm tractors or equipment. An estimated 100 of these were fatal. Estimates are based on reports by state traffic authorities classifying vehicles by body style, not vehicle use. Although farm tractors and equipment were involved in a small portion of total motor vehicle accidents nationally (less than 0.05%), the percentage of all fatal motor vehicle accidents involving farm equipment was almost five times greater. Mortimer (1983), analyzing similar data, concluded that exposure for the general public is limited because total numbers are low, but personal injury risks may be substantial. Earlier, Burke (1968) reported 280 fatalities nationwide in 25,000 accidents involving farm equipment on public roads during 1967. Almost half of these accidents involved collisions with motor vehicles.

Although injury incidents with tractors and other farm machinery occurred more frequently in the farm yard or fields, public right-of-way was the third most frequent environment for Iowa tractor-related injuries during 1992 (Iowa Department of Public Health, 1993). Fifteen percent of all tractor-related injuries occurred on a public roadway. During 1992, 59% of Iowa agricultural work-related injuries caused by motor vehicles involved in farm work occurred on public right-of-way. Lehtola et al. (1994) investigated 131 Iowa tractor-related fatality events that occurred from 1988 through 1992. Eleven percent of fatalities were on public roadways and involved other vehicles. Fourteen percent of 136 fatalities were this type of collision. Motor-vehicle occupants were 12 of the 19 fatalities in this category. Twenty-one percent of fatalities events, tractor overturns on roadways, did not involve other vehicles.

In Iowa, the term "farm vehicle" is used for equipment classification in Department of Transportation reports. "Farm vehicle" is defined by an investigating officer and use of the term limits the specific interpretation of statistics for tractors and self-propelled agricultural equipment. The Iowa Department of Transportation (J. Emery, 1993, personal communication) recorded 305 motor vehicle collisions involving farm vehicles during 1992. Farm vehicle accidents represented just 0.4% of all motor vehicle accidents, but 0.6% of all personal injuries and 2.3% of all fatalities. When farm equipment is involved in a motor vehicle accident, the chance of a fatality is increased. Forty-eight percent of Iowa collisions involving farm vehicles occurred from October through December. Rear-end collisions were the most frequently reported accounting for 43% of fatal collisions involving both tractors and other vehicles on Iowa's public roadways from 1988 through 1992 (Lehtola et al., 1994). Other frequent collisions were motorists attempting to pass tractors turning left (29%) and head-on collisions (29%). Lehtola et al. (1994) reported that some motorists striking the farm vehicle from the rear never braked and noted the importance of adequate lighting and marking.

Glascock et al. (1995b) determined from 803 two-vehicle crashes in Ohio that the most frequently reported collision type was when a farm vehicle was struck at an angle. Angle collisions were 25% of the total, while rear end collisions were 15% and sideswipe-passing collisions were 13%. Glascock also determined that at dark condition, rear end collisions were the largest type with 42% of 147 dark condition crashes.

Hill et al. (1992) surveyed the status of 29 tractor safety components on 136 New York dairy farms. Damaged, non-functional, or absent components found were combined into a safety score. A correlation between tractor age and safety score was reported. A greater prevalence of safety deficiencies was observed with increasing tractor age.

Shortening daylengths and the change from daylight to standard time during harvest may contribute to dangerous conditions. Sunrise and sunset times (Naval

Almanac Office, 1993) during harvest for two Iowa locations near the eastern and western borders of the state were determined. After changing to standard time, a grain wagon unloaded after 1700 h at a commercial Iowa elevator will have to travel public right-of-way after sunset. Sunset occurs even earlier in eastern portions of the central time zone.

State Requirements and *ASAE Standards*

Glascock et al. (1995a) reviewed state codes for lighting and marking of agricultural equipment. Inconsistencies were noted in requirements among states. Definitions of slow moving and farm vehicles vary from state to state.

Iowa code (Legislative Services Bureau, 1992) requires tractors and tractor-towed implement combinations traveling less than 40 kph (25 mph) on public right-of-way to display an ASAE approved (*ASAE Standards*, 1993a) slow moving vehicle (SMV) emblem visible from the rear. At any time from sunset to sunrise tractors and tractor-towed implement combinations must display a minimum of one white light visible 150 m (500 ft) from the front, and one red light and one amber flashing light visible 150 m (500 ft) from the rear. Iowa code does not specify hitch requirements for implements of husbandry.

ASAE standards for lighting and marking of agricultural field equipment on public right-of-ways (*ASAE Standards*, 1993b) specify more lighting and marking than the 1992 Iowa code requirements:

- At least two white headlamps, the same height and laterally centered about the tractor centerline, visible from the front.
- At least one red tail lamp, positioned less than 1.5 m (5 ft) left of the vehicle centerline, visible from the rear.
- At least two amber flashing warning lamps symmetrically mounted, visible both from the front and rear. If turn signals are provided, these lamps are used as turn indicators.
- At least two red reflectors marking left and right projections (may be a part of tail-lamp lens), visible to the rear.
- One SMV identification emblem visible to the rear (*ASAE Standards*, 1993a).

If towed equipment extends more than 1.2 m (4 ft) left of the hitch, an amber reflector marking the front left projection is to be visible to oncoming traffic (*ASAE Standards*, 1993b). Towed equipment extending more than 10 m (33 ft) behind the hitch are to have amber reflectors visible from the side and spaced at maximum intervals of 5 m (16 ft).

ASAE standards for agricultural equipment towed on highways recommends a retainer on the hitch pin (*ASAE Standards*, 1993c) and a safety chain attached by a hook latch with an ASAE tag specifying the towed-load gross weight (*ASAE Standards*, 1993d).

The presence of safety equipment (including proper lighting, marking, rollover protection and hitch safety equipment) on tractors and wagons is important because of documented risks. An inventory of safety equipment on tractors and wagons during harvest would indicate if equipment operators have these safety devices. The objectives of this project were to:

- Determine if lighting and marking safety equipment required by state law or recommended by ASAE standards, and roll-over protective structures (ROPS) were present on tractors at commercial Iowa grain-elevator checkpoints.

- Determine if the presence of such safety equipment varied with tractor age.
- Determine if lighting, marking, and hitch safety equipment required by state law or recommended by ASAE standards were present on wagons and hitches at these checkpoints.

Materials and Methods

Data collection was planned as part of an educational, community-based project using teams of vocational agriculture students (FFA) to conduct checks at selected Iowa commercial grain elevators. This method of data collection also increased safety awareness during harvest among Iowa equipment operators.

Checking tractor and wagon safety equipment for operation on public right-of-ways at grain elevators had the advantage of surveying a captive audience waiting to unload grain. Although the tractors and wagons surveyed were a sample of those unloading grain at specific commercial elevators, operator selection for road worthiness precluded sampling representing all tractors on the represented farms.

A standardized checklist was developed to limit delay for equipment operators at the elevator. To simplify and facilitate evaluation by FFA student inspectors, current ASAE standards were used for all inspections. Equipment was evaluated as to whether it could meet the current standard; the ability of older equipment to meet ASAE standards as of its manufacturing date was not measured. Iowa code requirements were enforceable regardless of equipment age. Fourteen individual lighting, marking, and hitch items for the Iowa code and current ASAE standards and the presence of a ROPS were included on the standardized checklist. In addition, inspectors noted the tractor make and model and asked the equipment operator the approximate age of the tractor.

A lesson plan was developed for use in the vocational agriculture classroom by the instructor prior to conducting equipment checks. Lesson-plan objectives were for students to: (1) be able to identify the importance of lighting, marking, and hitch equipment for road transport; (2) become familiar with checks and proper maintenance of such equipment; and (3) describe Iowa code requirements and ASAE standards for such equipment. The plan included a laboratory exercise for checking sample equipment at the school shop area.

The equipment check was designed for teams of four students each, two equipment evaluators, one data recorder, and one supervisor. A key task of the supervisor was to ensure the safety of those working around the check area. Teams were encouraged to define an inspection area and follow a systematic inspection sequence. Items to be inspected were grouped within zones graphically depicted on the check sheet.

Prior to a safety evaluation, the operator was asked to lock the brakes or put the tractor in park, shut off the engine, remove the key, dismount, and hand the key to the supervisor. The opportunity to refuse participation was given to each operator. Students were encouraged to supply the equipment operator with a refreshment break away from the tractor operator's station during the check and to provide safety information to reinforce the need to check equipment. Data were recorded on the check sheet and summary sheet. Identified safety problems were explained, and the operator was informed about the status of the equipment compared with Iowa code and ASAE standards immediately following the evaluation. Students were encouraged to immediately replace unacceptable SMV emblems and to direct the operator to local sources of service and materials to repair other safety deficiencies.

At several sites, a local sponsor or the FFA chapter supplied replacement SMV emblems at no cost.

Vocational agriculture chapters throughout Iowa were recruited during summer 1992 to use the check as a community service project to increase safety awareness. Seven chapters, at least one chapter from each of the four geographic quadrants of the state, participated. Each chapter received: (1) a copy of the lesson plan; (2) a standardized inspection check sheet; (3) a summary report form to record data; and (4) examples of a correctly logged inspection check sheet, and summary report. A single copy of five brochures describing various aspects of tractor and wagon lighting and marking and tractor rollover protection was also included. Additional copies of these brochures, for students to use with equipment operators, were supplied upon request. All other materials were copied locally.

For data analysis, each item of safety equipment observed followed a binomial distribution because it either did or did not comply with Iowa code or ASAE safety standards. To determine if a safety item was likely to be in compliance on a majority of tractors and wagons at the elevators, it was hypothesized that compliance with each safety item had a probability ≤ 0.5. Actual percentage in compliance measured at the elevators was then compared to the hypothesis of probability ≤ 0.5. This statistical test used a normal approximation of the binomial distribution (Steel and Torrie, 1980). If the hypothesis was false for an item, this indicated at least a 95% chance that a majority (more than half) of the tractors and wagons arriving at the elevator would comply with the safety standard.

To determine if differences existed with tractor age for safety item compliance with standards, tractors were divided into three age classes so that each class had a similar number of tractors. A Chi-square (χ^2) test (Steel and Torrie, 1980) was used to determine if differences existed for safety item compliance among these three tractor age classes.

Results and Discussion

A slower than average harvest during 1992 resulted in intermittent unloading at commercial grain elevators. Because fewer grain transports unloaded during a fixed period of time, usable data was received from five chapters that surveyed at six elevator sites scattered in each of the four geographic quadrants of Iowa (Northeast, Southeast, Northwest, and Southwest). Participating sites were self-selected. At most sites data was taken for a two to three hour period during each of three or four days that were suitable for harvesting. Data collected represents tractors and wagons transporting grain to these sites and did not represent the entire Iowa tractor and wagon population.

Participating FFA chapters commented favorably on the project. A typical quote was, “It’s just good to keep farm safety out in front of the people”. All grain elevator sites cooperated and encouraged the check. Most equipment operators appreciated the check and no refusal of inspection was reported.

The quality of student inspector evaluations was examined by internal checks and site visits. Internal checks comparing compliance of safety equipment with both the Iowa code and the ASAE standard were used to eliminate incorrect inspections. Less than one percent of returned data indicated that vehicles met the ASAE standard but not Iowa code, indicating an inspection was incorrectly made. A total of 130 inspections were returned with usable data. Omitted data on some inspections reduced the total tractors and wagons checked for ASAE standards to 105, except for hitch-pin retainer for which the number of wagons was 106.

Tractor Status

Table 1 presents the percentage of tractors complying with Iowa code by tractor age class. A majority of tractors in each age class as measured by a probability greater than one half ($Z \geq 1.65$, $p < 0.05$), met compliance for at least a single front white light and a SMV emblem. Tractors less than eight years of age had at least one rear red light ($Z = 3.10$, $p < 0.05$)and an amber flashing light ($Z = 2.51$, $p < 0.05$). Only tractors less than eight years of age met all Iowa code requirements for travel between sunset and sunrise.

There were no statistical differences among age groups for compliance with each safety item. Only half the items listed showed a linear trend of increasing compliance with decreasing age. Because only tractors less than eight years of age had a probability greater than one half of having rear lighting, data suggest maintenance or presence of rear red and amber flashing lights may be a problem. There was no statistical difference ($\chi^2 = 4.12$, 2df, $p > 0.10$) among age-groups for compliance with SMV requirements.

Tractors in each age class met the criteria of ASAE standards for two front white lights, two front amber flashing lights, and a ROPS (table 2). Tractors less than eight years of age met the ASAE standards for at least one rear red light and two rear amber flashing lights, but not for two rear red reflectors.

Within the zero-to-seven-years age class for tractors, the smaller percentage of compliance for two rear red reflectors (62%) compared with the percentage of compliance for the single rear red light (71%) may have been due to a missing or inoperative taillight. This difference may have also occurred because of a small sample size. Tractors in the middle-aged class had a slightly greater percentage of compliance for rear red reflectors (47%) than for a rear red taillight (45%). An opposite trend for tractors in the oldest age class may have indicated that only one red taillight was supplied as original equipment by the manufacturer.

A statistically significant difference ($\chi^2 = 19.2$, 2df, $p < 0.05$) existed among age classes for ROPS equipped tractors. Tractors less than 15 years old towing grain loads to the commercial elevators were more likely than tractors more than 15 years old to have ROPS. Such a difference may reflect ROPS availability for some tractors. Myers and Snyder (1995) estimated the number of non-ROPS tractors including only makes/model with 10,000 units or more. They determined that 18% of the 1,602,673 tractors had no ROPS available. They also determined that over 60% of the tractors older than 19 years were without ROPS. No differences among age classes were measured for other safety items.

Only tractors less than eight years old had a probability greater than one half of complying with Iowa code or the ASAE standard for rear lighting. This indicates

Table 1. Percentage of tractors, by age class, complying with Iowa code safety standards

	Tractor Age (years)		
	0-7*	8-14†	15+*
Item Description	Percentage Complying		
Forward white light, one	98‡	100‡	96‡
Rear red light, one	74‡	53	61
Rear amber flashing light, one	70‡	61	57
SMV emblem	87‡	79‡	70‡

* Number of tractors in age class = 46.
† Number of tractors in age class = 38.
‡ Probability of safety standard compliance greater than one half at the $p < 0.05$ level.

Table 2. Percentage of tractors, by age class, complying with ASAE lighting and marking safety standard (S279.9) and ROPS standard (S383.1)

	Tractor Age (yrs)		
	0-7*	8-14†	15+‡
Item Description	Percentage Complying		
Front white lights, two, same height, laterally centered about tractor centerline	86§	95§	87§
Front amber flashing lights, two, same height, laterally centered about tractor centerline	76§	82§	65§
Rear red light, one, within 1.5 m (5 ft) of centerline	71§	45	54
Rear amber flashing lights, two, laterally centered about tractor centerline, within 400 mm (16 in.) of lateral extremity	71§	50	48
Rear red reflectors, two, marking extreme left and right projections (tail light lens acceptable)	62	47	39
ROPS||	100§	97§	67§

* Number of tractors in age class = 21.
† Number of tractors in age class = 38.
‡ Number of tractors in age class = 46.
§ Probability of safety standard compliance greater than one half at the $p<0.05$ level.
|| Safety standard compliance among age groups is different at the $p<0.01$ level.

that maintenance or lack of the presence of rear lighting and reflectors for tractors over seven years old was a problem. Results of the lighting inspections may have been affected because checks were made between sunrise and sunset. Iowa code does not specify lighting requirements during these times. However, front lighting was better maintained than rear lighting.

The slight differences for similar item categories between Iowa code and ASAE standards indicated the relative ability of tractors to meet ASAE standards more exacting compared to the state law. Combining all tractor age classes, only 9% of tractors meeting the Iowa code for front lights did not meet the ASAE standard. Similarly, 6% of tractors meeting the Iowa code for rear lighting did not meet the ASAE standard. A slight increase among new tractors meeting ASAE standards for rear amber flashing lights compared with those meeting Iowa code was related to sample size.

For similar safety items, differences between compliance for Iowa code and ASAE standards were small. Greater differences among percentages complying with safety standards are noted when comparing front to rear lighting and marking. As measured by those items with a compliance probability greater than one half, tractors in the middle and older age groups met all front lighting and marking requirements but did not meet any rear lighting and marking requirement except the SMV emblem.

Wagon and Hitch Status

Among safety items checked, wagons had a compliance probability greater than one half only for an SMV emblem ($Z=6.31$, $p<0.05$) and a retainer on the hitch pin ($Z=3.21$, $p<0.05$, see table 3). Compliance percentages for all other wagon safety items were lower than those of all tractor safety items. The data indicated a greater compliance for front and side amber reflectors than for rear lighting and marking. The only rear marking for most wagons was an SMV emblem. Although not shown in table 3, for rear red lights on towed wagons, a statistically significant difference existed ($\chi^2=6.29$, 2df, $p<0.05$) among wagons attached to tractors of different age classes. The percentage of wagons complying with standards was greater for wagons behind tractors over 14 years of age (Iowa = 43%, ASAE = 39%).

Differences between Iowa code and ASAE standard compliance percentages for similar items were 5% for the rear red light and 6% for the rear amber flashing light.

Table 3. Percentage of wagons and tractor/wagon hitches complying with lighting, marking, and hitch safety standards of the Iowa code and ASAE (S276.3, S279.9, S318.10, and S338.2)

Item Description	Percentage Complying
Iowa code*	
Rear red light, one	31
Rear amber flashing light, one	25
SMV emblem	81†
ASAE standards‡	
Rear red light, one, less than 1.5 m (5 ft) left of centerline	26
Rear amber flashing lights, two, laterally centered about wagon centerline, within 400 mm (16 in.) of lateral extremity	19
Front amber reflector, one, marking extreme left [if wagon extends 1.2 m (4 ft) left of hitch]	38
Side amber reflector(s), spaced at intervals not to exceed 5 m (16 ft) [if wagon(s) extend(s) more than 10 m (33 ft) behind hitch point]	37
Rear red reflectors, two, marking extreme left and right projections	18
Hitch pin retainer pin used	66†
Hitch safety chain used with hook latch and ASAE tag with load specification	30

* Number of wagons = 106.
† Probability of safety standard compliance greater than one half at the $p<0.05$ level.
‡ Number of wagons = 105, except hitch-pin retainer pin number of wagons = 106.

Compliance with the more specific ASAE red-taillight specification required only repositioning of the light from the right to the left side of the wagon. Comparing the two ASAE hitch standards, wagons were likely to have a retainer on the hitch pin but unlikely to have used an approved safety chain.

Application

With the exception of ROPS, no statistically significant differences of compliance with safety standards among tractor age classes were measured. Five of ten tractor safety item categories did not exhibit a linear trend of increased compliance with decreasing age. The data do not agree with increasing safety deficiencies with increasing age as found on New York tractors (Hill et al., 1992). Disagreement could have resulted from different types of farm operations. Myers and Snyder (1995) observed differences based on type of farm operation. They reported cash grain farms had 48% of tractors with ROPS while dairy farms had 37% of tractors with ROPS. In addition, equipment operators may have rejected the use of some older tractors as being unsafe to transport grain on public roadways.

The probability of complying with front-lighting Iowa code and ASAE standards for tractors at these elevators was greater than one half. Inspection of rear lighting and marking of tractors, however, found only the SMV emblem to have a probability of meeting compliance standards greater than one half. A possible explanation for this difference is the maintenance of front white lighting for field work and the availability of an SMV emblem at minimal cost. Rear red lighting may be viewed as benefiting others (motorists) but lacking direct production value. Front amber lights that have no immediate impact on agricultural production however, were maintained by operators. Upkeep of rear lighting and reflectors may be more difficult if their positions are exposed to mechanical damage during equipment use and positioning operations. Mud, manure, snow, and other debris could cover or damage rear lenses. Equipment operators should be encouraged to maintain rear lighting and marking. Manufacturers should evaluate lens and reflector placement for possible damage and coverage by debris.

Safety lighting and marking on wagons was generally neglected with the exception of the SMV emblem. Equipment operators put greater reliance on the SMV emblem for rear marking than any other device. Greater percentages of compliance for amber front and side wagon reflectors also suggest a problem with the maintenance or presence of rear reflectors and lighting. Wagon manufacturers should evaluate placement, and operators should be encouraged to maintain and procure the necessary lighting and reflectors.

Several low cost options to improve lighting and marking are suggested by the data. Operators with a single red taillight right of the wagon centerline may comply with ASAE standards by maintaining the light within 1.5 m (5 ft) left of the centerline. The addition of red and amber reflectors where suggested does not require any external power supply. At a minimum, operators should remove debris from lenses and reflectors as well as replace bulbs and damaged lenses and reflectors. Because of the frequency of rear-end collisions throughout the day, operators should add rear lighting, if needed, beyond just maintaining existing safety items and adding reflectors.

The use of a retainer on the hitch pin is becoming an accepted practice with many operators, but the use of an approved safety chain is not. Equipment dealers and others should promote retrofitting of chains.

Conclusions

At the Iowa commercial grain-elevator sites surveyed, the data support the following conclusions about tractors and wagons delivering grain:

- Tractors had a probability greater than one half of meeting Iowa code or ASAE safety standards for: headlights, front amber flashing lights, SMV emblem, and ROPS. Tractors less than eight years old met safety standards for rear amber flashing lights and rear taillight.
- Tractors less than 15 years old were more likely to be equipped with ROPS than were tractors more than 15 years old. Compliance with other safety items did not significantly differ among tractor age-groups.
- Wagons had a probability greater than one half of meeting Iowa code and ASAE safety standards for an SMV emblem and retainer on the hitch pin. Other wagon safety items all had lower compliance than did all tractor safety items.

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