Agricultural Equipment on Public Roads

Prepared by:
The Committee on Agricultural Safety and Health Research and Extension

North Central Education/Extension Research Activity Committee 197
Cooperative State Research, Education, and Extension Service
United States Department of Agriculture

February 2009

Recommended citation:
Committee on Agricultural Safety and Health Research and Extension. 2009. *Agricultural Equipment on Public Roads*. USDA-CSREES, Washington, DC.

TABLE OF CONTENTS

PREFACE

The United States Department of Agriculture (USDA) promotes high priority multistate research and education/extension through its land grant university system. Multistate research projects are managed by State Agricultural Experiment Station (SAES) directors in partnership with the Cooperative State Research, Education, and Extension Service (CSREES) of the USDA, other research institutions and agencies, and with the Cooperative Extension Service (CES). In this way, technological opportunities and complex problem solving activities, which are beyond the scope of a single SAES, can be approached in a more efficient and comprehensive way

SAES directors are organized into four regional associations. One of these regional associations, the North Central Regional Association of Agricultural Experiment Station Directors, approved the efforts of the North Central Region-197 Committee on Agricultural Safety and Health Research and Extension in 2000. In 2005, this committee was re-appointed under the revised name North Central Education/Extension Research Activity Committee (NCERA) 197. The work of this committee is conducted under the project title "Agricultural Safety and Health Research and Extension." and published works are credited to the Committee on Agricultural Safety and Health Research and Extension. Though the NCR- and NCERA 197 committees were appointed by the North Central Region, the work scope and membership makeup is at a national level.

NCERA committees provide opportunity for scientists, specialists, and others to work cooperatively to solve problems that concern more than one state, share research data, and coordinate research and other types of activities. Additionally, these committees serve to integrate education (academic and/or extension) and research on a particular topic where multistate coordination or information exchange is appropriate; have expected outcomes; convey knowledge; and are peer reviewed. The duration of the committee may be up to five years. Committee membership is comprised of scientists appointed by participating state research and extension directors, USDA representatives, and other professionals with appropriate expertise and interest.

Effective solutions to the hazards and risks associated with moving agricultural equipment on public roads are not easily devised or implemented, but until all stakeholder groups become engaged in the effort, little progress can be expected. The Committee on Agricultural Safety and Health Research and Extension took on this project because we feel the topic is timely, problematic, wide-spread, and under-appreciated by almost everyone. We hope the publication of this document provides enhanced understanding and direction to the dialog that must continue with a wide array of public and private stakeholders to improve the safety and health for people working and traveling on public roads all across rural America.

Committee on Agricultural Safety and Health Research and Extension
February, 2009

ACKNOWLEDGMENTS

The Committee on Agricultural Safety and Health would like to thank several people who helped to develop and review various drafts of this white paper. Many, though not all, are members of the National Institute for Farm Safety (NIFS) or the American Society of Agricultural and Biological Engineers (ASABE). We are particularly indebted to the NIFS organization as they let us use a Professional Development Workshop opportunity at their 2008 Annual Meeting and Conference to present a draft of the document to gain important feedback and suggestions about our white paper.

The Committee also thanks Murray Madsen, from the University of Iowa and a non-committee member who provided original text on the Uniform Vehicle Code and on lighting and marking of agricultural equipment, and Marsha Hull, Graphic Artist at Penn State, for final design and layout of our document.

Cover photo courtesy of the Mississippi State University, Office of Agricultural Communications.

EXECUTIVE SUMMARY

A Committee on Agricultural Safety and Health Research and Extension was formed by the United States Department of Agriculture Cooperative State Research, Education, and Extension Service (USDA-CSREES) North Central Regional (NCR) Administrators in 2000. The goal of the committee, designated as NCR 197, was to more effectively use the land grant system's research and extension capacity in cooperation with the experience of those who live and work in agriculture to reduce work-related injuries, illness, death, and property loss. The NCR 197 Committee produced a landmark publication in 2003 titled, *National Land Grant Research and Extension Agenda for Agricultural Safety and Health: National Agenda for Action*. Twelve priorities for action were identified:

1. Sensors and guarding systems
2. Agricultural equipment on public roads
3. Agriculture confined spaces
4. Emerging technologies
5. Human factors engineering and design
6. Management of agricultural emergencies
7. Livestock handling and housing systems
8. Public policy issues
9. Capital and management intensive vs. family labor intensive operations
10. Fire detection and suppression
11. Agricultural safety education and training
12. Special populations and enterprises

In 2007, the committee chose to develop a white paper on Agricultural Equipment on Public Roads. This white paper has multiple purposes: a) to help identify research, policy and extension/outreach priorities for the U.S. Departments of Agriculture and Transportation, the National Institute for Occupational Safety and Health, state departments of agriculture, transportation and law enforcement, county government, and production agriculture based organizations; and b) to identify possible design and practice standards, goals, or guidelines for farm equipment manufacturers, standard setting organizations, and government agencies.

Issues relating to operating agricultural equipment on public roads are multi-faceted and complex. This report looks at a number of issues, however, not all issues can be examined in the same detail because the literature in some areas is at best sparse. Issues addressed in this report include rural/urban traffic interface, state and federal regulations, higher speed tractors, and transport of workers on public roadways with farm equipment.

Several suggestions in the areas of research, standards, education/outreach and policy have been developed to help guide future work as a result of this review.

Research is needed to:

1. Develop criteria to better describe characteristics of crashes between motor vehicles and agricultural equipment using standard reporting terminology. This would include developing model definitions, methods, and data collection instruments. Examples of standard data elements would include:
   a. Road and visibility conditions

   b. Ages of victims
   c. Vehicle and agricultural equipment features (including type and size of equipment, whether machine or animal-drawn, and compliance with current lighting and marking, braking, and other related standards)
   d. Environmental conditions (e.g., time of day, rain, icy)
   e. Driving actions of motorists and equipment operators
   f. Whether victim(s) was operator or rider
   g. Alcohol and/or drug abuse.
2. Assess the understandability, effectiveness, and best use practices of lighting and marking of agricultural equipment on public roadways. This should include both urban and rural motorists and would focus on topics such as:
   a. Slow moving vehicle (SMV) and Speed Indicator Symbol (SIS) emblems
   b. Animal-drawn buggies, wagons and implements, including culturally acceptable lighting and marking systems for Anabaptist populations
3. Improve engineered systems for higher speed tractors, self-propelled machines and towed equipment. This would include such topics as:
   a. braking systems
   b. suspension systems
   c. steering controls
   d. hitching/attachment mechanisms
   e. proximity sensors to motor vehicles
   f. tires
   g. ROPS
4. Examine the existence and consistency of farm equipment roadway safety information in driver's education programs across the United States.
5. Expand behavioral studies on allowing extra riders on farm equipment to include adults, and such factors as extra riders on public roads for work-related purposes.
6. Determine the effects of graduated licensing for youth to operate agricultural equipment on public roads, including higher speed tractors and self-propelled machines.
7. Examine impacts and implications of county and state land use policies regarding operation of agricultural equipment on public roadways. This would include topics such as:
   a. Risks of crashes with motor vehicles
   b. Exclusions and exemptions from road traffic regulations and restrictions
   c. Transportation of agricultural hazardous materials on rural public roads
   d. Economic issues and costs associated with heavy agricultural loads on rural public roads.

Engineering design standards should:

1. Be better connected to research findings.
2. Have better representation during their development by researchers and end-users.
3. Be used to incorporate automatic and passive protection for drivers and riders of agricultural equipment during public road use.
4. Be continually reviewed for the possibility of adoption of new technologies into design standards and practices.

Safety education programs are needed to:

1. Educate both the public and farmers on:
   a. Best practices for operating agricultural equipment on public roads.
   b. Approaching slow moving vehicles on public roads, including the purpose and use of the SMV and SIS emblems.
   c. The effects of exclusions and exemptions from road traffic regulations and restrictions.
2. Work with local and state law enforcement agencies to increase awareness of county and state traffic laws related to farm equipment among law enforcement officers.
3. Encourage Amish buggy manufacturers to utilize marking and lighting systems and components that meet current ASABE, SAE, and DOT standards.

Policy is needed to:

1. Promote the purpose and use of the SMV and SIS emblems in every state's driver's license manual and driver's education program.
2. Encourage a more comprehensive Uniform Vehicle Code to be developed and adopted nationally and by states. This new code should better address modern types and uses of agricultural equipment on public roads. Topics that should be addressed include:
   a. Registration of farm equipment for use on public roads.
   b. Qualifications and training for operating agricultural equipment on public roads.
   c. Extra riders on farm equipment, including on tractors, self-propelled machines and towed equipment.
   d. Animal-drawn buggies, wagons and equipment.
3. Provide for a consistent source of funding for research into hazards, risks and best safety practices for operating agricultural equipment on public roads.
4. Encourage land-use policies by state and local governments to better manage the interaction of farming and non-farming uses of public roadways in their jurisdiction.
5. Encourage stricter enforcement by local and state police of SMV emblem misuse.

LIST OF FIGURES

1.0 INTRODUCTION

A Committee on Agricultural Safety and Health Research and Extension was formed by the United States Department of Agriculture Cooperative States Research, Education and Extension Service (USDA-CSREES) North Central Regional (NCR) Administrators in 2000. The goal of the committee, designated as NCR 197, was to more effectively use the land grant system's research and extension capacity in cooperation with the experience of those who live and work in agriculture to reduce work-related injuries, illness, death, and property loss. The NCR 197 Committee produced a landmark publication in 2003 titled, *National Land Grant Research and Extension Agenda for Agricultural Safety and Health: National Agenda for Action*. Twelve priorities for action were identified:

1. Sensors and guarding systems
2. Agricultural equipment on public roads
3. Agriculture confined spaces
4. Emerging technologies
5. Human factors engineering and design
6. Management of agricultural emergencies
7. Livestock handling and housing systems
8. Public policy issues
9. Capital and management intensive vs. family labor intensive operations
10. Fire detection and suppression
11. Agricultural safety education and training
12. Special populations and enterprises

The name of the committee was changed in 2005 to the North Central Education/Extension Research Activity Committee (NCERA) 197. In 2007 the committee chose to develop a white paper on the second identified priority, Agricultural Equipment on Public Roads.

Terms such as “agricultural-related” and “agricultural vehicles”, when used in the context of traffic or roadway safety, are not usually well-defined nor understood. In this document, we address collisions involving production agriculture equipment in public roadway incidents. This includes tractors, self-propelled machines, and the equipment that may be towed by or attached to tractors and self-propelled machines[1]. The type of agricultural equipment that is excluded includes trucks, equipment and other vehicles not used for production agriculture.

Motor vehicle collision fatalities are a well-documented tragic fact of our nation. Over 41,000 people died in motor vehicle crashes in 2007 (National Highway Traffic Safety Administration 2008). In addition, the National Highway Traffic Safety Administration (NHTSA) reported a total of 2.5 million people were injured by collisions. The sheer volume of non-agricultural-related collision fatalities and injuries is overwhelming in proportion to agricultural-related collision fatalities and injuries. The proportion from agricultural vehicles is only 0.2 percent of the total number of vehicles involved in traffic crashes. This is an established trend for agricultural equipment collisions over several years (NHTSA, 2006, 2005). In 2007, NHTSA reported that farm

[1] Refer to Society of Automotive Engineers Standard J1150 and American Society of Agricultural Engineers Standard S390.4 for official designations.

equipment (excluding trucks) had 87 fatal crashes in 2006, representing 0.2 percent of the major category identified as "Other Vehicle" types. The combined "Other Vehicle" type was reported as having 622 fatalities or 1.1 percent of the total number of fatal crashes.

However, these agricultural related collision fatalities and injuries have more significance when placed in the context of the agricultural population or when evaluated based on exposure rates in the agricultural industry. For example, a 2003 report on work-related roadway crashes by the National Institute for Occupational Safety and Health (NIOSH) showed that while Agriculture, Forestry and Fishing had a comparatively low frequency of fatal crashes among all industrial divisions at 7.2%, the 4th lowest of the 11 major divisions, the industries' rate per 100,000 full-time equivalent workers of 2.58 FTEs was the third highest rate (Pratt, 2003).

The importance of these fatalities and injuries are significant to agricultural safety professionals. At the same time, because the proportion of incidents is so small in comparison to all public roadway crashes, federal, state and local government bodies rarely give this area of roadway safety any attention. Nor do non-agricultural industry groups. For example, the American Traffic Safety Services Association (ATSSA) recently published, "*Toward Zero Deaths: A Vision for Safer Roads in America*". This document contains a section and recommendations for improving high-risk rural roads but does not mention agricultural equipment (ATSSA, 2008).

Issues relating to operating agricultural equipment on public roads are multi-faceted and complex (Costello et al., 2008). There are many ways to identify and discuss major areas of concern. This report looks at a number of issues but not all issues can be examined in the same detail because the literature in some areas is at best sparse. Issues addressed in this report include rural/urban traffic interface, state and federal regulations, higher speed tractors, and transport of workers on public roadways with farm equipment. Issues with much less or barely existent literature include licensing of drivers and the interface between rural and urban/suburban populations.

Whether there is literature or not, some issues do not have clear lines of separation. For example, issues involving rural/urban interface, higher speed tractors, lighting and marking of equipment, and licensing of drivers are all deeply intertwined. And all issues can be placed within the context of regulations for agricultural equipment on public roads, or within causes of crashes between faster moving motor vehicles and slower moving agriculture equipment. Finally, many issues are researched only sporadically which means that the literature that is available may be outdated or have important gaps. This report provides known facts on the four issues named above and offers suggestions for the future.

2.0 THE RURAL/URBAN TRAFFIC INTERFACE

2.1 PROBLEMS IDENTIFIED BY US:

- There is little attention paid to issues surrounding safe movement of agricultural equipment on public roads by federal, state or local governments.
- Public roadway crashes involving agricultural equipment are, comparatively, few in number but an important part of overall crashes involving agricultural populations.
- The impacts of changing demographics that characterize the urban/rural interface are not well researched or understood.
- Many details of public road crashes involving agricultural machinery and motor vehicles are unknown or lack sufficient detail to aid prevention efforts.
- There is no available data that provide for an accurate assessment of the injuries, deaths, or property losses associated with motor vehicle crashes involving horse-drawn buggies or implements.

2.2 WHAT DO WE KNOW ABOUT THESE PROBLEMS?

The continuing urbanization of traditional agricultural production areas has led to a substantial increase in the mix of agricultural equipment and licensed motor vehicles on public roads (Committee on Agricultural Safety and Health Research and Extension, 2003). Farms are increasing in size, often by the acquisition of non-contiguous land. There is a trend towards greater management of farms by renters and leasers with custom operators performing many field operations. Many farm commodity prices are at an all-time high, and new production techniques continue to result in higher levels of production per unit. There is current interest in biomass as a fuel source. This suggest that famers' and ranchers' production output will reach new levels. Add to these factors the incursion of housing developments, shopping plazas and other urban developments onto lands once used exclusively for agriculture, and regular movement of urban dwellers to small lifestyle acreages. A result of all these factors and changes is an increased mix of farm equipment with faster moving motor vehicles on public roadways and is referred to collectively as the rural/urban interface.

The percent of crashes where one or more died defined as rural or urban is 53.7% and 44.1%, respectfully, with the remaining 2.2% identified as unknown. The highest percent of fatal crashes in rural locations--42.5%-- occurred on rural roads posted at 55 mph (88.5 km/h) or higher (NHTSA 2007). While farm tractors and other self-propelled equipment (excluding farm trucks) number less than .05% of total motor vehicles nationally, the percentage of fatal motor vehicle incidents involving farm equipment is almost five times higher (Hanna et al, 1997).

According to Abrams (1993) the United States nighttime highway fatality rate is 3-4 times higher than that of daytime. While falling asleep at the wheel and driving while intoxicated are significant factors, reduced vision plays a substantial role. This is pertinent because of the aging population of farmers and persons in rural areas in general. As we age, there is a tendency to become farsighted and not to see as clearly up close. In addition, the range and speed at which the pupil adjusts to differing levels of illumination decreases. More specifically, there is a 50% reduction in retinal illumination at age 50

compared to age 20 and 66% reduction at age 60 (Abrams, 1990). At night, the peripheral retina must be stimulated at sufficient intensity for an object to be detected. If the stimulus is not strong enough, the brain is unable to process the information in time to avoid a collision. Essentially, the elderly need more light.

2.2.1 PUBLIC ROAD CRASHES.

Studies reporting crash data involving farm equipment or farm vehicles are difficult to compare because terminology is not precise. For example, a state's definition of *farm vehicle* may or may not include pickup or livestock trucks, depending in part, upon whether or not a state has an exemption for trucks that are operated only within a certain distance of the farm operation. Additionally, many studies do not precisely define terms such as farm vehicle or farm equipment. For these reasons, comparisons of crash data among states must be interpreted very cautiously. In the studies reported below, the terms *vehicle* and *non-farm vehicle* typically include all types of motor vehicles, including pickup and dump trucks. The terms *farm vehicle* and *agricultural equipment* typically includes tractors and self-propelled agricultural machines, and may or may not include towed farm equipment.

Peek-Asa et al. (2007) recently reviewed characteristics of crashes between farm equipment and motor vehicles in Iowa. Included in their article were findings and points from previous studies relating to crashes between agricultural equipment and motor vehicles.

- Crash fatality rates in the most rural counties are almost double the rate in urban counties (Eberhardt et al., 2001; Baker et al., 1992).
- Rural crashes are more frequent, more severe, and more likely to result in death than urban crashes (Baker et al., 1987).
- Certain types of crashes, such as those between motor vehicles and farm vehicles, are unique to rural environments and usually involve slow moving tractors with trailing equipment and higher speed motor vehicles (Peek-Asa et al., 2004; Costello et al., 2003).
- The environment of the rural road contributes to increased crashes and more severe injury outcomes (Graham, 1993; Karlaftis & Golias, 2002; Peek-Asa et al., 2004).
- In crashes involving farm vehicles, the farm vehicle occupant was killed nearly twice as often as occupants of the other vehicle (Gerberich et al., 1996).

Contrary to the findings of Gerberich et al. (1996), Peek-Asa et al. (2007) found that non-farm vehicle drivers were 5.2 times more likely to be injured than farm vehicle/equipment drivers. Peek-Asa et al. (2007) attributed these differences in findings to differing crash criteria. For example, Gerberich et al. (1996) examined only fatal outcomes while Peek-Asa et al. (2007) examined all reported crashes regardless of injury outcomes.

Peek-Asa et al. (2007) also noted that their findings were similar to those found by Pinzke and Lundqvist (2004).

Costello et al. (2003) examined the public health impacts of farm vehicle public road crashes in North Carolina. As reported by Costello et al. (2003), this study included a comparison of farm vehicle public road crash rates among the states of Florida, Iowa,

Michigan and North Carolina. These data are reported in Table 1 below (Table 2 in original document) and illustrates a wide range of incident rates among these states.

Table 1. Comparison of farm vehicle public road crash rates for selected U.S. states.

States	Average Number of Cases per Year (resulting in injuries	Population (1999 est.)	Average Number of Crashes per Day (365 days/year)	Average number of Crashes per 100,000 Population per year
Florida	150[a]	15.1 million[b]	0.41	0.00
Michigan	251[c]	9.9 million[b]	0.69	2.54
Iowa	309[d]	2.9 million[b]	0.85	10.66
North Carolina	300[e]	7.7 million[b]	0.82	3.90

[a] University of Florida, 1991
[b] U.S. Census Bureau, 1999
[c] Michigan Farm Bureau, 1999
[d] Schwab, 1997
[e] Hughes and Rodgman, 2000
Table reprinted with permission from ASABE

Costello et al. (2003) further indicated that 2 in every 100 crashes involving tractors, which may or may not be towing other farm equipment, and 1 in every 100 crashes involving other farm equipment (self-propelled or towed farm vehicles other than tractors) leads to a traffic death. The concern among farmers about the risk of driving agricultural equipment on public roads was revealed in North Carolina (Luginbuhl et al., 2003). This study focused on farmers' perceptions of roadway safety. The study was instigated after a group of farmers in one region of North Carolina reported an increase of traffic on rural roads and their need to drive their equipment on these roads was viewed as their number one workplace hazard. In their review of farm equipment crashes, tractors were found to be involved in the majority of crashes on roadways. When these crashes occurred 34% of the drivers of non-farm vehicles were cited. Typical citations included failure to reduce speed, improper passing, and driving left of center. In 23% of the cases where the farm operator was issued a citation, lighting and yield violations were noted. In at least 11% of the cases where the farm operator was cited, the crash occurred in the evening and the tractor was not utilizing adequate lighting.

Additionally, when asked about their safety precautions, 92% of the study participants responded they used signal lights to warn others and 88% indicated they had an SMV emblem on the back of their equipment. Interestingly, though, when asked questions on whether other farmers knew the lighting requirements for farm equipment traveling on public roadways or whether most farmers were aware of the safety marking for farm equipment recommended by the American Society of Agricultural Engineers (ASAE) there was not strong agreement (Note: ASAE changed their name to American Society of Agricultural and Biological Engineers (ASABE) in 2005). A majority of respondents agreed that an effective way to reduce crashes would be to ensure that: a) all farm vehicles had blinking or flashing lights; b) road officials placed diamond-shaped caution signs showing a tractor ahead on roads with heavy farm traffic; and c) roadway shoulders were wide enough to allow farmers to drive totally on the shoulder. Finally, the study found that most farmers believed that driving their tractor on rural roads was more dangerous now than it was five years before. A similar concern was expressed in 1990 in a survey reported in a *Farm Journal* magazine story (Ottey and Fink, 1990). In

this survey, farmers reported that their number one concern was that of public road travel to reach fields and markets.

A more recent study by Costello et al. (2008) examined driver, vehicle, public roadway, and farm enterprise characteristics for their combined association with farm vehicle public roadway crash group membership. North Carolina farmers experiencing a public roadway crash from 1992-2003 (n=200) were compared with a non-crash control group (n=185). The researchers found that five characteristics were associated with increased odds of crash group membership in the combined model. These characteristics were: 1) use of non-English speaking drivers; 2) use of non-family hired help drivers; 3) types of non-farm vehicle public road use; 4) farm injury history; and 5) use of younger farm vehicle drivers.

While acknowledging several limitations associated with their methods and instruments, the majority of their findings were in the expected direction, based on other studies cited in their literature review. Two findings that were not in the expected direction—increased odds of crash involvement—were that farms with older farm vehicle drivers and farms with low farm income were less likely crash group members. A recent study in Iowa (Freeman et al., 2008) found that a sample of 1,343 Iowa farmers did not rank transporting agricultural equipment on public roadways as a very stressful event in comparison to numerous other events. Potentially stressful events could be ranked between 100 (most stressful) and 0 (least stressful). Transporting agricultural equipment was ranked 53.2%. One message that these recent studies (Costello et al, 2008; Freeman et al., 2008) give is reinforcement that there is still much to be learned about the issues and characteristics of operating agricultural equipment on public roadways.

2.2.2 SPECIFIC TYPES OF CRASHES.

Several researchers have identified some of the common types of crashes involving agricultural equipment (Costello et al., 2003; Hughes and Rodgman, 2000; Schwab and Miller, 1995). These common types of crashes include rear-end, left-turn, passing, crossroads, and oncoming collisions. Costello et al. (2003) reported five categories of farm vehicle operator traffic citations as vehicle equipment, unsafe movement, failure to yield, being left of the center line, and not signaling. These account for approximately 70% of all North Carolina farm vehicle public road citations from 1995-1999. There are also individual reports of these types of collision events from all around the nation that help illustrate the nature of these events.

Rear-End Collision. The rear-end collision is a common type of farm equipment vs. motor vehicle collision on public roads. Lehtola et al. (1994) reported that of fatal incidents involving tractors and motor vehicles that occurred on Iowa public roads from 1988-1992, 43% (6 of 14) were the tractor being hit from the rear. Gerberich et al. (1996) reported that a large proportion of farm vehicles are struck in the rear during daylight (24%) as well as night, dawn, or dusk hours (65%), compared with non-farm vehicles (4% and 4%, respectively). Costello et al. (2003) reported that the top traffic citation issued among North Carolina non–farm vehicle operator violations was failure to reduce speed (29.5%). The speed difference between agricultural equipment and other motor vehicles creates this potential hazard. It is easy to misjudge speed when approaching a slow-moving vehicle, you have only a few seconds to react and slow down. Agricultural

safety professionals frequently warn about this hazard (Abend and Hallman, 1995; Schwab and Miller, 2004; Petrea, 2004). For example, if you're driving 55 mph (89 km/h) and come upon a tractor that's moving 15 mph (24km/h) , it only takes five seconds to close a gap the length of a football field between you and the tractor. An actual example of this type of collision involved a tractor pulling two tobacco trailers on a highway a little before 6 PM being struck from behind by an automobile; the tractor operator was killed and the automobile operator was charged with failure to reduce speed.

Left-Turn Collision. The left-turn collision is another frequent type of farm vehicle collision on public roads. It happens when the farm equipment is about to make a left turn while the motorist behind the farm vehicle decides to pass. Schwab and Miller (1995) reported that there were 297 such collisions in Iowa during a five year period and that represents 22% of all farm vehicle collisions recorded. An actual example of this type of collision occurred when three people were injured when a tractor was turning left and was struck by an auto attempting to pass. The injured were the tractor operator, and the vehicle's driver and passenger.

Passing Collision. Costello et al. (2003) reported that the second most common traffic citation issued among North Carolina non–farm vehicle operator violations was improper passing (17.0%). Many collisions also occur when motorists pass farm vehicles going in the same direction. Some farm operators haul equipment that is extra wide or long, which motorists don't consider when they plan to pass. An actual example of this type of collision involved a car passing a tractor with a mower and the car struck the tractor wheel weights. Too few of the motoring public are aware of need not to pass at farm field entrances and farm building driveways.

Crossroads Collision. Farm operators transporting agricultural equipment face a challenge of taking their slow-moving equipment across an intersection. This becomes even more challenging when the cross traffic is moving at a high speed. An actual example of this type of collision involved a westbound combine failing to yield to a southbound semi at a highway intersection.

Oncoming Collision. Many collisions also occur when motorists pass oncoming farm vehicles. Some farm operators transport equipment that is extra wide or long, which motorists don't consider as they approach the farm equipment. An actual example of this type of collision involved a man in a car being killed after striking a planter being towed behind a tractor. The car then crashed through a guardrail and into the roadside ditch.

2.2.3 SPACES AND PERSPECTIVES.

A recent *Successful Farming* magazine story provides an example of how clear distinctions between rural and urban spaces are disappearing. Randy and Cheryl Miller had moved their farming operation 3.5 miles (5.6 kilometers) north of Ankeny, IA, when they were married 30 years ago. "Now Ankeny's on our south fence line and across the road", say the Millers (Tevis, 2008, p38). Increasingly, there is also a lack of space on rural roads. For example, in the same *Successful Farming* issue, Dr. Robert Aherin, University of Illinois extension agricultural safety specialist, noted that most paved rural roads are 18-20 feet (5-6 meters) wide while 70% of farmers in a *Successful Farming* online panel survey indicated they owned machinery over 13 feet (4 meters) wide (Tevis, 2008, pp36-37).

Wide machinery also becomes a big issue when farm machinery has to cross a rural bridge or work its way around utility poles, mailboxes and road signs. In many areas it is impossible for modern farm machinery to travel down rural roads and not take up well over ½ the road. The height of modern machinery and lower hanging pole lights, traffic signs, and utility lines and cables results in equipment shifting partially into the left lane to avoid these obstacles. Space is also an issue from the perspective of new divided highways in rural areas to handle increased traffic volumes because middle sections for crossing divided highways need to be wide and deep enough to safely handle today's large machinery.

Any examination of safely moving agricultural equipment on public roads should look at the perspectives of both agricultural and non-agricultural populations. While no research was found that directly compared the perspectives of these two populations on the same set of issues, surveys and interviews with farmers clearly show that they think the hazards and risk associated with moving their machinery on public roads are primarily due to the actions of the non-agricultural motoring public (Luginbuhl et al., 2003; Tevis, 2008). The reports by Luginbuhl et al. (2003) and Tevis (2008) suggest that farmers believe that traditional rural dwellers (including farmers) are more understanding and knowledgeable about encountering slow moving farm equipment on the road than urban and suburban dwellers, and that traditional urban dwellers are less patient and understanding when farm equipment slows their travel speed. Furthermore, it is not clear how well urban or suburban drivers understand what the lighting and marking on farm equipment means when encountering it on public roads.

2.2.4 HORSE-DRAWN BUGGIES AND IMPLEMENTS.

One transportation issue that is having a growing impact on some rural communities is the rapidly expanding presence of horse-drawn buggies and implements on public roadways being operated by members of Old Order Anabaptists communities, including the Amish and Old Order Mennonites. Members of these communities hold to selective and cautious use of technology to protect their families, communities and way of life. Some historians and sociologists argue that the use of horse-drawn vehicles is one of the most recognized or distinguishing features that separate Old Order Anabaptists from the rest of the culture (Hostetler, 1992; Scott, 1981; Kraybill and Olshan, 1994). Intentional rejection of personally owned motor vehicles and farm tractors, and reliance on horse powered transportation and farm implements are intended to keep Old Order families in closer proximity, keep farms smaller, present a witness of humility, and reduce the likelihood that their means of transportation would cause injury or death to other users of public roadways.

Historically, Old Order Anabaptists have been primarily concentrated in small rural communities in Pennsylvania, Ohio, and Indiana. Their small numbers and desire to remain separate from the world around them led to generally few highway-related problems. When collisions did occur between motor vehicles and horse-drawn vehicles, it was primarily the Old Order Anabaptists who received the brunt of the losses. Due to an explosive growth rate, however, there are currently approximately 375 Old Order Amish communities located in twenty-seven states and the province of Ontario, Canada. In addition, there are other expanding groups such as Old Order German Baptists and Wenger Mennonites who still rely on horse-drawn vehicles for transportation and farm

work. In some counties such as Lancaster County, Pennsylvania; Holmes County, Ohio; and LaGrange County, Indiana, there are several thousand horse-drawn buggies and implements that are used on local roads and the number of buggies may exceed the number of licensed motor vehicles. The result has been a growing number of reported highway crashes involving horses and buggies, some of which have involved multiple fatalities to buggy occupants.

Even though Old Order Anabaptist populations may, on the surface, appear to have many similarities, there are no uniform standards among the many affiliations of Old Order Anabaptists with respect to the design and use of horse-drawn carriages and implements. For example, buggies can be black, white, gray or a combination. Some affiliations within these communities allow rubber tires while others don't. Some allow the use of electric lights, reflective tape and Slow Moving Vehicle (SMV) emblems while other groups forbid their use (Kraybill and Olshan, 1994). These differences, and the tenacity to which they are defended, have been seen as barriers to developing uniform standards designed to enhance the safety of operating horse-drawn vehicles on public roadways.

The use of the SMV emblem on buggies has been central to one of the more intense conflicts that have occurred between Old Order Anabaptists groups and the general public. In some cases where the local pressure to adopt SMV emblems, reflective tape and electric lighting has intensified, the non-complying Old Order families simply moved to a more receptive community or to where the codes were not so severely enforced by local law enforcement. In Minnesota a group of Old Order families known as Swartzentrubers refused to use the SMV emblem and were ticketed by local law enforcement. This case was eventually reviewed by the U.S. Supreme Court and the decision of a lower court to overturn the citation was affirmed on the grounds of this group's beliefs that compliance with the state marking and lighting codes prevented them from freely practicing their religion (Zook, 1993).

There are no directly available data that provides for an accurate assessment of the injuries, deaths, or property losses associated with motor vehicle crashes involving horse-drawn buggies or implements. Some studies, however, can be considered suggestive. For example, a study of 217 farm-related injuries to children under the age of 18 from 14 states and Canada documented during 2002 identified less than one percent involving motor vehicle-related crashes or highway-related incidents (Gilliam et al., 2007). Based solely upon the frequency of injuries reported within the Old Order Anabaptist community, it would be difficult to make a strong case that the highway-related incidents they experience should be a high priority for intervention activities compared to other injury events. It does appear, however, that these incidents are occurring more frequently and often result in multiple fatalities and severe injuries because of the limited protection provided by horse-drawn carriages. In other words, the probability of these events may be low, but the severity of the consequences is high.

Grassroots efforts within the Old Order communities, primarily facilitated by Cooperative Extension programs in Pennsylvania, Ohio, and Indiana have resulted in a substantial increase in the voluntary use of enhanced marking and lighting on Old Order Anabaptist buggies and farm implements. In LaGrange County, Indiana, for example, the use of SMV emblems increased from less than 30% to over 85% through a community-wide awareness campaign.

Some communities have enhanced the safety of operators of horse-drawn buggies and implements by providing wider shoulders or “buggy lanes” along the road for these vehicles to operate outside the stream of higher speed traffic. Other communities have recognized the potential hazards associated with the co-mingling of high and low speed vehicles and have responded by reducing the posted speed limits and placing warning signs where there is frequent use of horse-drawn buggies and implements.

A national Amish buggy safety committee, which is comprised of buggy manufacturers from across the United States, has addressed issues such as the use of L.E.D. (light emitting diode) lighting technology, high capacity/long life gel-type batteries, use of retro-reflective tape and strobe lights, and the need for training younger buggy operators. A growing number of Old Order buggy and harness shops now carry a wide variety of safety accessories to help make buggies and implements more visible to other highway users.

In 2008, the American Society of Agricultural and Biological Engineers (ASABE) completed a standard that established a unique identification system for animal drawn vehicles on public roadways and highways. The ANSI/ASAE EP576.1 standard, "Lighting and Marking of Animal Drawn Equipment," is intended to complement existing laws, rules and regulations in individual states, providences and municipalities to provide a consistent lighting configuration for horse-drawn vehicles. The recommended practice includes proper lighting and marking of both the vehicle and the animal, such as the use of headlamps, tail lamps, battery-operated or generator-powered lighting systems, and retro-reflective material, as well as the display of the slow-moving emblem. The Recommended Practice will affect consistency with all carriages, carts, and buggies, not just those in Amish communities. It appears that the Old Order Anabaptist community is becoming more accepting of the use of marking and lighting accessories that meet current voluntary consensus standards.

2.3 LITTLE-EXAMINED ISSUES.

There are additional issues which anecdotally are known to increase hazards and risks for the motoring public but for which there appears to be little to no publicly available documentation. Some of these issues are:

- Collisions with farm animals (e.g., a cow, sow or horse) that are on a road as a result of a broken fence or open gate and are hit by the motorist.
- Rural road bridge damage and failure from larger and heavier grain and cotton trucks and wagons, manure spreaders, and tractors and tillage equipment.
- Agricultural equipment carrying hazardous materials like anhydrous ammonia, pesticides and animal waste in quantities that can pose significant environmental and personal injury risks.
- Use of alcohol and other drugs during operation of agricultural equipment on public roadways.

Likewise, there are ideas which could possibly increase the safety of farmers operating their equipment on public roads but for which there is little to no publically available documentation regarding implementation or effectiveness. Some of these ideas are:

- Use of escort vehicles. Other large size vehicles with wide loads are required to use one or more escort vehicles. This suggests that a motor vehicle with hazard

lights flashing traveling in front of, behind, or both, of agricultural equipment provides increased visibility and warning to other motorists for immediate caution. Importantly, there is scarce evidence that either escort drivers or motorists know what they are responsible to do.

- Use of fixed and mobile rural road signs that warn of tractors or other slow moving farm equipment, especially in heavy traffic times (spring tillage, fall harvest) or locations (roads leading to rural storage facilities or markets).
- Farmers making greater use of trucks, including semi-trucks, to haul produce to storages or markets rather than using tractors and wagons. This is already occurring as farms become larger and more dispersed but as a specific intervention to reduce farm equipment vs. motor vehicle crashes, it has not been evaluated.

3.0 FEDERAL AND STATE REGULATIONS

3.1 PROBLEMS IDENTIFIED BY US:

- Guidance relating to farm equipment operation on roadways and lighting and marking for it provided by the national Uniform Vehicle Code is inadequate and not embraced in state regulations.
- There is a bewildering array of state vehicle code regulations governing lighting and marking of agricultural equipment on public roads.
- These state vehicle code regulations have not kept pace with advances in lighting and marking made by the voluntary consensus standards process implemented by farm equipment manufacturers.
- Tractors have historically been identified as moving 25 mph (40 km/h) or less but some new tractors may now travel up to 45 mph (72 km/h).
- States are inconsistent in how they address young operators of agricultural equipment on public roads.

3.2 WHAT DO WE KNOW ABOUT THESE PROBLEMS?

3.2.1 UNIFORM VEHICLE CODE AND LIGHTING AND MARKING OF AGRICULTURAL EQUIPMENT.

Perhaps the most fundamental issue surrounding the requirement of lighting and marking of agricultural equipment is directed towards the confusion of how state laws define a slow-moving vehicle or implement of husbandry. Some states define a slow moving vehicle by its maximum speed; and some define it by use or vehicle type (Glascock et al., 1995). This variation in legal definition allows for a wide variety of accepted lighting and marking configurations, and perhaps is a contributing factor to the motoring public's lack of recognition of an agricultural slow moving vehicle.

Legislation dealing with farm tractors and agricultural equipment generally reflects how such machines, historically, were used in the field and spent minimal time on the road. In the United States each state has its own traffic code, although most of the rules of the road are similar for the purpose of uniformity, given that all states grant reciprocal driving privileges (and penalties) to each others' licensed drivers. Ironically, there is a "Uniform Vehicle Code" (UVC) which is a privately prepared set of suggested model United States traffic codes prepared by the National Committee on Uniform Traffic Laws and Ordinances (NCUTLO).

The NCUTLO is a private, non-profit membership organization dedicated to providing uniformity of traffic laws and regulations through the timely dissemination of information and model legislation on traffic safety issues. This committee adopted its first code in July, 1926. The Code consisted of four acts: vehicle registration; antitheft; operators' and chauffeurs' licensing; and a fourth part, regulating the operation of vehicles on highways. this section prescribed rules of the road, speed limits, rules against reckless driving or driving while intoxicated, and those governing size, weight, and equipment of vehicles (Barber, 1927).

Some states adopt selected portions of the code as written by the NCUTLO or with modifications, while other states create their own versions. Initially, both the regulations suggested by the UVC for lighting of agricultural equipment on public roads and

provisions provided by manufacturers on agricultural equipment moved forward, incrementally, evolving roughly in sync into the middle 1950s. Thereafter, both industry consensus standards and what manufacturers provided improved regularly. But neither the model UVC nor the requirements passed by state codes kept pace. For example, at the time of the U.S. Department of Transportation's January 1971 "Agricultural Tractor Safety on Public Roads and Farms" report to Congress, only one state had laws conforming in all respects with the UVC and only twelve were in substantial agreement with the UVC with regard to agricultural tractors and self-propelled machines. Furthermore, one-third of all states still required only the minimal lighting devices that were considered feasible four decades earlier.

The U.S. Department of Transportation's report to Congress concluded that if immediate corrective action was necessary, enabling legislation at the state level based on the UVC was the mechanism recommended to improve illumination and turn signaling. Furthermore, such legislation should be developed to address retrofitting equipment since it would otherwise take an estimated 30 years before new lighting presentations would dominate if they were introduced solely on new equipment (U.S. DOT, 1971). The report did not include antique equipment, a category of vehicle that is much more popular and visible today than in 1971.

The 2000 edition of the NCUTLO UVC offers that, after a specified date left to State discretion, every new tractor and self-propelled machine be equipped with at least two headlights, at least one red rear light mounted as far left as practicable, and two red rear reflectors (NCUTLO, 2000). The UVC 2000 also calls for every agricultural tractor and self-propelled machine to be fitted with hazard warning lights visible to the front and to the rear, whenever on a roadway, to warn operators of other vehicles about the presence of a special traffic hazard requiring unusual care. Moreover, every such vehicle is to be equipped with hazard warning lights required for that vehicle by applicable standards of the U.S. Department of Transportation at the time of its manufacture. However, no such U.S. Department of Transportation standards have been found.

For every combination of an agricultural tractor and towed implement, according to UVC 2000, the tractor is to be equipped as described in the preceding two paragraphs and the towed implement equipped as follows. If the towed unit extends over 4 feet (1.2 meters) to the rear of the tractor or obscures any light, the implement shall be equipped with at least one red rear light mounted as far left as practicable and at least two red rear reflectors. If the towed implement extends over 4 feet (1.2 meters) to the left of the tractor's centerline, the implement shall be equipped with an amber reflector to the front as far left as practicable. If the towed implement or its load obscures either of the flashing warning lights of the tractor, the towed implement shall be equipped with hazard warning lights as prescribed for the tractor, along with two red rear reflectors positioned to delineate the combination's extremes of width. In some instances reflectors are substituted for lights.

3.2.2 STATE VEHICLE CODES.

Additional comprehensive reviews of state highway regulations and lighting and marking for agricultural equipment were published in the early 1990s. For example, Becker (1991) contacted all 50 state highway commissioners or directors to ask about highway safety laws for agricultural vehicles, equipment and personnel. Eicher et al.

(1995) and Glascock et al. (1995) have reported on their reviews of all 50 states for regulations concerning lighting and marking of agricultural equipment on public roads. Based on an earlier survey of state agencies (McFarland, 1965), Eicher et al. (1995) developed a new set of 29 questions regarding agricultural road safety issues. From the Eicher et al. (1995) study, Glascock et al. (1995) compiled the questions and answers to 15 questions relevant to front and rear lighting patterns. These questions and answers provided a summary of state law requirements. The questions and answers, as presented by Glascock et al. (1995), are listed below and in Table 2, respectively.

1. How many headlights are required on tractors and self-propelled agricultural equipment (SPAE)?
2. Are tractors and SPAE headlights required for day use?
3. Headlights must be visible at all times specified from a distance of no less than?
4. How many taillights are required for day use on tractors and SPAE?
5. Are taillights required for day use on tractors and SPAE?
6. The taillights of tractors and SPAE must be visible, at all times specified, from a distance no less than?
7. What is the required color of the taillights? (R=Red; A=Amber)
8. Are amber flashing lights required/permitted? (NP=Not Permitted; NR=Not Required; R=Required)

12. Are turn signals required on tractors and SPAE?
13. Are SMV emblems required on tractors and SPAE?
14. Are white lights permitted to show to the rear on tractors and SPAE?
15. Does towed equipment and implements of husbandry need to have taillights/flashers/reflectors if the taillights/flashers/reflectors on the towing vehicle are visible?

19. Are amber flashing lights on implements of husbandry required/permitted?
21. Are turn signals required on implements of husbandry?
25. Are tractors, SPAE, or implements of husbandry required to display a warning flag?

Table 2. A compendium of state laws as of 1995 pertaining to the lighting and marking of agricultural equipment .

	Question Numbers and Answers														
State	**1**	**2**	**3 (m)**	**4**	**5**	**6 (m)**	**7**	**8**	**12**	**13**	**14**	**15**	**19**	**21**	**25**
Alabama	1	No	152	1	No	152	Red	NR	No	Yes	NIC	Yes	NR	NIC	No
Alaska	NIC	NIC	NIC	NIC	NIC	NIC	NIC	NIC	No	Yes	NIC	NIC	NIC	NIC	Yes
Arizona	1	No	152	1	No	152	Red	NR	No	No	NIC	No	NR	NIC	No
Arkansas	2a	No	152	2a,b	No	152	Red	NR	No	No	Yes	Yes	NR	No	No
California	2	No	61	1	No	152	Red	NR	No	Yes	No	NIC	NR	No	Yes
Colorado	2a	No	61	1	No	152	Red	NR	No	Yes	NIC	Yes	NR	No	No
Conn.	2	No	61	2	No	305	Red	NR	No	No	NIC	Yes	NR	No	No
Delaware	1	No	152	2b	No	152	Red	NR	No	No	NIC	NIC	NR	No	No
Florida	2	No	61	1	No	305	Red	R	No	Yes	NIC	Yes	NR	No	No
Georgia	2	No	152	1	No	152	Red	NIC	No	Yes	NIC	Yes	NR	No	No
Hawaii	2	No	61	2	No	61	Red	NR	No	Yes	NIC	No	NIC	NIC	Yes
Idaho	2a,e	No	152	2a,b,e	No	152	Red	R	No	Yes	NIC	No	NR	No	No
Illinois	2	No	305	2	No	305	Red	R	No	Yes	NIC	NIC	R	No	No
Indiana	2a,e	No	152	2a,b	No	152	Red	R	No	Yes	NIC	Yes	R	No	No
Iowa	2	No	152	1	No	152	Red	R	No	Yes	No	Yes	R	No	No
Kansas	2	No	61	1	No	305	Red	R	No	Yes	NIC	Yes	R	No	No
Kentucky	1	Yes	31	1	Yes	31	W/R	NR	No	Yes	Yes	No	NR	No	No
Louisiana	2a	No	152	1j	No	152	Red	NR	No	Yes	NIC	Yes	NR	No	No
Maine	2	No	15	1	No	31	Red	NIC	NIC	No	NIC	NIC	NIC	NIC	NIC
Maryland	2	No	61	2	No	305	Red	NR	No	Yes	No	Yes	NR	No	No
Mass.	1	No	NIC	1	No	NIC	Red	NR	No	Yes	No	NIC	NR	No	NIC
Michigan	1	No	152	1	No	92	Red	NR	No	Yes	NIC	Yes	NR	No	No
Minnesota	1	No	152	1e	No	152	Red	NR	No	Yes	No	Yes	NR	No	No
Mississippi	2	No	152	1	No	152	Red	NR	No	Yes	NIC	Yes	NR	No	No
Missouri	1	No	152	1	No	152	Red	NR	No	Yes	NIC	NIC	NP	NIC	NIC
Montana	2a,e	No	152	2b	No	152	Red	NR	No	Yes	NIC	Yes	NR	No	No
Nebraska	2	No	152	1	No	152	Red	NR	No	Yes	NIC	No	NR	No	No
Nevada	2	No	152	1	No	305	Red	R	No	Yes	NIC	Yes	NR	No	No
New Hamp.	2	No	305	1	No	305	Red	NR	No	Yes	No	Yes	NR	No	No
New Jersey	1	No	152	1	No	152	Red	NR	No	No	NIC	Yes	NR	No	No
New Mexico	2a	No	152	1	No	152	Red	NR	No	Yes	No	Yes	NR	No	No
New York	2	No	305	1	No	152	Red	NR	No	Yes	No	NIC	NR	No	No
N. Carolina	1	No	152	1	No	152	Red	NR	No	No	No	NIC	NR	No	No
N. Dakota	2a	No	305	1	No	305	Red	NR	No	No	No	Yes	NR	No	No
Ohio	1	No	305	2b	No	305	Red	NR	No	Yes	No	No	NR	No	No
Oklahoma	2a,e	No	152	2a,b,e	No	152	Red	NR	No	Yes	NIC	Yes	NR	No	No
Oregon	2	No	152	1	No	NIC	NIC	NR	No	Yes	NIC	NIC	NR	No	No
Penn.	2	No	305	2	No	NIC	Red	R	No	Yes	No	No	NR	No	No
Rhode Isl.	2	No	23	1	No	152	Red	NP	No	Yes	NIC	Yes	NP	No	No
S. Carolina	2	No	61	1	No	152	Red	NR	No	No	No	Yes	NR	No	No
S. Dakota	1	No	152	2	No	305	Red	NP	No	Yes	Yes	No	NP	No	No
Tennessee	1e	No	152	1e	No	152	Red	NIC	No	Yes	No	Yes	NIC	No	No
Texas	2	No	31	1e	No	305	Red	R	No	Yes	NIC	Yes	Rf	No	No
Utah	2	No	305	1e	No	305	Red	R	No	Yes	NIC	Yes	Rf	No	No
Vermont	2	No	46	1	No	NIC	Red	NIC	No	Yes	NIC	Yes	NR	No	No

(a) Only one (1) is required when tractor is not equipped with electrical system; (b) Two (2) reflectors and one (1) taillight may be used instead; (e) One (1) lamp or reflector must be placed as far as left as practicable. (j) Two are required only on self-propelled agricultural equipment. NIC: not in code. Table reprinted with permission from ASABE.

This type of study has not been replicated. It is shown here as an example of the types of studies that are needed on an ongoing basis.

3.2.3 SLOW MOVING VEHICLE EMBLEM.

In the late 1950s a 10-year retrospective study of fatal tractor accidents was conducted by Walter McClure and Ben Lamp, both of the Department of Agricultural Engineering at The Ohio State University, to understand their nature and causes (McClure and Lamp, 1961). The research indicated a significant number of fatalities related to highway travel of slow-moving vehicles. A research proposal written by Ken Harkness, also an agricultural engineer at Ohio State University, and funded through the Automotive Safety Foundation (1961-62) further focused understanding of slow moving vehicle collisions and resulted in the development of a unique SMV emblem. Early data estimated that 65 percent of the motor vehicle crashes involving slow moving farm equipment were rear-end collisions. The Ohio State Highway Patrol, county sheriffs, and municipal police cooperated in the research by gathering detailed data on 708 farm equipment vs. motor vehicle crashes (Harkness and Stuckey, 1962).

In 1962, under the supervision of Ken Harkness, the design and testing of the SMV emblem was completed. A $1/16^{th}$ scale highway simulator had been constructed to test human recognition rates of different shapes and colors mounted on simulated slow moving vehicles. After testing various designs, a triangular-shaped emblem with a 12 inch (30 centimeters) high fluorescent orange center and three 1.75 inch (4.4 centimeters) wide reflective borders was determined to be the most effective design for day and night visual identification. The emblem quickly became known as the SMV (slow moving vehicle) emblem.

The Goodyear Rubber and Tire Company sponsored initial public exposure to the SMV emblem in 1962. An emblem mounted on the back of a farm wagon and towed by a Ford tractor made a trip from Portland, Maine to San Diego, California. The first formal introduction of the SMV emblem was at a University of Iowa Invitational Safety Seminar in 1962. Carlton Zink, of Deere and Company, then became an avid promoter of the SMV emblem and played a major role in the adoption of the emblem as a recommendation by the ASAE in 1964[2] as R276 "*Slow Moving Vehicle Identification Emblem (SMV Emblem)*". Among other things, this standard established the definition of a slow moving vehicle as agricultural machinery or implements of husbandry that traveled at a speed of 25 mph (40 km/h) or less.

In 1963, Novice G. Fawcett, President of The Ohio State University, dedicated the SMV emblem to the public. Also in 1963, the *Agricultural Engineering* journal printed its first article with color illustrations about the SMV emblem (Harkness, 1963). In less than two years from the emblem's first date of availability, Nebraska, Michigan, Ohio, and Vermont adopted legislation requiring the emblem to be used on slow moving vehicles. In 1971, the SMV emblem became the first ASAE Standard to be adopted as a national standard by the American National Standards Institute (ANSI). In 1992, the American Society of Agricultural Engineers designated the development of the SMV emblem as an ASAE Historic Landmark.

The SMV emblem standard was significantly improved when the standard was revised in 1997 with version S276.5. This standard adopted the use of new, more advanced, retro-reflective and fluorescent material available on the market. Emblems that meet this standard are visible at about 1,000 feet (305 meters) whereas emblems meeting older versions of the standard are visible to the driving public between 400 to 600 feet

[2] Historically, ASAE standards were first published the year following formal adoption.

(122 to183 meters). In addition, degradation of the visibility characteristics of the emblem is significantly reduced under the Florida sunlight test. Emblems meeting the S276.5 standard generally last about twice as long as the older material before fading below levels set by the standard. Since this significant revision of the standard, most states have adopted the newer version of the standard for slow moving vehicles manufactured since about 2001. Illinois is the only known state that requires all implements of husbandry operated on public roadways to display an SMV emblem, new or old, that meets ASAE S276.5 or greater. Most manufacturers have complied with the new standards since they were adopted by ASABE.

Most farm equipment on farms have an SMV emblem on it. For example, in a survey of Pennsylvania Farmers Association members (now known as Pennsylvania Farm Bureau), farm operators indicated that 77-85% of their most frequently operated tractor was equipped with an SMV emblem (Ambe,1994). Hanna et al. (1997) found that a large majority of tractors and wagons (70 to 87%) in lines at a sample of commercial grain elevators in Iowa were equipped with an SMV emblem. However, the condition or quality of the SMV may be more problematic.

Anecdotally, many farm safety professionals routinely observe SMV emblems that are severely faded, bent, cracked or on upside down. West and May (1998) found in their inspections of tractors and PTO-powered implements at auction sites in New York state that 80.7% of tractors and 62.7% of PTO-powered implements had missing or defective SMV emblems. The researchers did not distinguish between “missing” or “defective’, nor did they define the term defective. It is reasonable to presume that the term “defective” included badly faded and bent and cracked emblems. Some support for the assumption that many, if not most, of these deficiencies were faded, bent or cracked emblems comes from a study by Murphy et al. (1998). In this study, trained farm safety auditors in Central Pennsylvania considered the quality of SMVs on a cohort of cooperating farm operators’ three most used tractors. Only 32.5% of the 193 SMV emblems were found to be “on, properly placed and bright in color”.

Despite the longevity and use of the SMV emblem by farmers, there is a significant problem with recognition of the SMV emblem by the general driving public. Garvey (2003) reported that, while older drivers understood the meaning of the emblem better than their younger counterparts, overall emblem comprehension was fewer than 30%. According to Garvey, the improvement of the SMV emblem’s comprehensibility must be addressed through more consistent and accurate motorist education, increased enforcement of state motor vehicle codes (particularly against illegal use of the emblem to mark fixed objects), and emblem modification to make it more iconic in nature or at least to ensure that it appears the same to approaching drivers in daylight and at night.

Lehtola (2007) confirmed that many states do not provide any information on the emblem in the educational materials provided to those in drivers’ education programs or for those studying on their own to take their state driver’s test. Lehtola found that in many states there is no mention of the hazards associated with sharing the road with farm equipment in driver’s education manuals, and that the training drivers receive regarding recognition of SMV emblems and farm equipment is inconsistent. Driver’s manuals in nine states (several being highly agricultural states) had no mention of farm equipment or slow-moving vehicles at all. This is a substantial finding because for SMV emblems to be a potential factor in avoiding collisions, it requires that a good SMV emblem be

visible to the rear of farm equipment and other drivers must know what the emblem represents.

Another issue is how well SMV emblem regulations are enforced. There is concern that many counties and states are not adequately enforcing the regulations they have. This was brought out in a study by West and May (1998) who conducted a survey of equipment at New York farm auctions to measure the amount of safety defects on equipment sold. Based on ASAE standards, SMV signs were defective or absent on 60-80% of equipment.

Finally, a question can be raised of the SMV emblem's relevance to today's agricultural equipment. When the SMV emblem was initially devised and tested during the early 1960s, most tractors did not travel faster than 20 mph (30 km/h) and did not tow equipment much wider than the tractor itself. The only self-propelled equipment found on public roads were combines and swathers and they typically moved even slower than tractors. Nor was miss-use of the SMV emblem as common as it is today (see the section below).

3.2.4 MISUSE OF THE SMV EMBLEM.

A continuing problem in most states is the misuse of SMV emblems. They can often be found marking the entrance to driveways, mailboxes, gates, and on vehicles they are not intended to be used on. Most states have laws that do not allow the misuse of the emblem and allow for the perpetrators to be fined. For example, in Illinois anyone that uses an SMV emblem on any vehicle or structure other than those vehicles classified as slow moving vehicles in their statutes can be fined up to $75. However, enforcement is generally very lax or non-existent. Most law enforcement officers are either not familiar with this aspect of their respective state motor vehicle regulations or they choose not to enforce the law for a variety of reasons.

While there has been no known research conducted to verify what affect misuse of the emblem has on collision risk with farm equipment, it is likely there are negative impacts. For instance, because the emblem is no longer a unique identifier of slow moving agricultural equipment, faster traveling motorists may not be as likely to slow down as quickly as they approach from the rear. As explained earlier, the potential hazard of this situation becomes apparent when considering the rate of closure between vehicles traveling at a posted speed and slow-moving vehicles.

3.2.5 SPEED INDICATOR SYMBOL (SIS).

Currently, tractors and agricultural trailers are classified as slow moving vehicles. But as tractors begin to rival the speeds of trucks, the current legal classifications may need to be revised to either change the definition of a slow moving vehicle or exempt tractors that can operate at 40 mph (64 km/h) and faster. Iowa lawmakers have already begun to wrestle with these issues. In 1999, the state changed the speed classification for SMVs from 25 to 35 mph (40 to 56 km/h) to keep faster tractors covered under the law.

Ohio is one of the country's leaders in the number of high-speed tractors traveling the roadways. According to the Ohio Farm Bureau, two counties in Ohio have the highest concentration of high-speed tractors in the United States. Speeding citations have been issued to tractor operators operating at speeds over 25 mph (40 km/h) because the current law in Ohio requires that tractors must remain at 25 mph (40 km/h) or less and display a

Slow Moving Vehicle (SMV) emblem. One problem Ohio lawmakers recognized was that there were no legal signs available to place on the tractors that would warn other drivers of the vehicle's presence on the road. It was illegal to place the large orange slow moving vehicle (SMV) emblem on the tractors because they are capable of going over 25 mph (40 km/h).

During the same time period that the Ohio State Highway Patrol was issuing tickets because of higher speed tractors, the American Society of Agricultural and Biological Engineers was in the process of adopting (in 2005) Standard S584 "*Agricultural Equipment: Speed Identification Symbol (SIS)*". The scope of this standard is primarily directed to identifying farm machinery that has been designed in its original equipment configuration for specified ground speeds greater than 25 mph (40 km/h). Because of the obvious connections, S276 "*Slow Moving Vehicle Identification Emblem (SMV Emblem)*" and S279 "*Lighting and Marking of Agricultural Equipment on Highways*" were revised to include the SIS on higher speed tractors in 2006.

Ohio legislation, enacted in October 2007, permits any unit of farm machinery that is designed by its manufacturer to operate at a speed greater than 25 mph (40 km/h) to do so as long as the unit displays both an SMV emblem and the Speed Identification Symbol (ASAE Standard 584.1) and that the vehicle does not exceed this documented speed (Ohio Revised Code, 2007). For towed implements, legislation requires both SMV and SIS emblems be displayed, and that the implement's SIS match the SIS on the tractor.

This legislation requires the operator to have documentation of manufacturer's stated maximum speed of the vehicle, and maintain reasonable control while operating the vehicle on roadways. In addition, the operator of a unit of higher speed farm machinery who wishes to travel on a public street or road faster than 25 mph (40 km/h) must have a valid driver's or commercial driver's license.

A flaw in this legislation is that it requires the two SIS emblems (on the tractor and implement) to match. This may result in either: (1) operator citations unjustified from a safety perspective; or (2) encouraging operators to apply SIS emblems inappropriately to implements not rated for that speed, causing potentially unsafe situations.

The first scenario, citations that are unjustified from a safety perspective, can occur when an implement with a given SIS emblem (as applied by the implement manufacturer) is pulled by a tractor with either a lower SIS emblem or none at all. The SIS emblem represents an official manufacturer's rating of the highest safe speed at which an implement can be pulled; there is nothing unsafe about an implement being pulled by a tractor with a lower SIS rating. Furthermore, tractors without SIS emblems were not manufactured to travel fast enough to merit an SIS emblem, and thus would also have a top speed lower than that of the implement with the SIS emblem. Since only a small percent of tractors currently in use have SIS emblems, it is quite likely that new implements with an SIS emblem applied by the manufacturer will be pulled by tractors without an SIS rating, which is perfectly safe. The law, as is, could actually encourage tractor operators to apply SIS emblems to tractors that cannot travel at that speed simply to avoid being cited.

The second scenario, inappropriate application of SIS emblems to implements not rated for that speed, could result when an operator of a tractor with an SIS emblem must pull an implement without an SIS emblem, i.e., an implement that has not been rated for a speed above 25 miles per hour (the speed above which an SIS emblem is required). To be

safe, the tractor operator should not pull the implement faster than 25 mph: to pull it faster when it has not been rated for a higher speed risks an unsafe situation. But to avoid citations, operators might apply their own SIS emblems to the implement, since law enforcement is only looking to see that they match. This inappropriate application most likely will result in the implement being pulled at a speed for which it was not rated, but more importantly, gives the false impression to others that the implement was tested and rated by the manufacturer, especially future purchasers of such implements on the used-equipment market. The SIS emblem must only represent manufacturers' official ratings, so an inappropriately applied emblem could result in the second owner towing the implement at unrated speeds and also potentially cause liability for the person who originally and inappropriately applied the emblem.

3.2.6 VOLUNTARY CONSENSUS STANDARDS.

ASABE, the American Society of Agricultural and Biological Engineers (formerly American Society of Agricultural Engineers, ASAE) is a technical society and the recognized standards developing organization for agricultural field and farmstead equipment in North America. ASABE standards are consensus documents developed and adopted to meet standardization needs within the scope of the Society; principally agricultural field equipment, farmstead equipment, structures, soil and water resource management, turf and landscape equipment, forest engineering, food and process engineering, electric power applications, plant and animal environment, and waste management (ASABE, 2007). ASABE Standards, Engineering Practices, and Data initially approved prior to the society name change in July of 2005 are designated as 'ASAE', regardless of the revision approval date. Newly developed Standards, Engineering Practices and Data approved after July of 2005 are designated as 'ASABE'.

ASAE Standards, Engineering Practices, and Data are informational and advisory only. Use of these standards by anyone engaged in industry or trade is entirely voluntary and conformity does not ensure compliance with applicable ordinances, laws, and/or regulations. There were various forms and forums, ad hoc recommendations and guidance for agricultural equipment lighting prior to the 1950's (S Cedarquist, private conversation, December, 2007). The first published compendium of ASAE standards was in 1954 (Agricultural Engineers Yearbook, 1954). It included a standard, ASAE S213, "*Safety Lighting for Combinations of Farm Tractors and Implements*". The preface to that standard states:

> "Act V, Section 137c, Uniform Act Regulating Traffic on Highways, revised and approved by National Committee on Uniform Traffic Laws and Ordinances, 1952, established regulations for safety lighting of farm tractors and implements when transported on the highway at night. Specifications essential to conformity with these regulations were accordingly developed by the Advisory Engineering Committee of the Farm Equipment Institute, and were adopted February, 1954, as an official standard of the American Society of Agricultural Engineers."

The Farm Equipment Institute was the former name of the industry trade association for manufacturers of farm equipment. Its name, scope, and functions have changed over time but somewhat similar work continues within the current Association of Equipment Manufacturers (AEM) (AEM, 2007).

The 1954 ASAE safety lighting standard called for tractor manufacturers to provide an SAE (Society of Automotive Engineers) standard electrical connector socket. This outlet provided power to a safety lamp, showing red to the rear and amber to the front, which tractor manufacturers were to "make available". It called for a means for the lamp to be mounted on the tractor, or optionally at the left extremity of the towed implement and be energized through a 22-foot (6.7 meters) electrical cable running from the outlet on the tractor. In addition, towed implement manufacturers were to make available either two taillights or two reflectors showing red to the rear and indicating as nearly as practicable the extreme left- and right-rear extremities of the towed implement. If implements mounted on the tractor obscured the tractor's lighting, that lighting was to be moved or replicated on the implement. Mounted implements extending more than 4 feet (1.2 meters) to the left of the tractor's centerline were required to have reflectors or an additional taillight. In addition, providers of self-propelled agricultural equipment were to make available lighting and marking consistent with that for tractors and tractor-implement combinations.

A new standard for lighting and marking of agricultural tractors, self-propelled machines, implements, and implements in combination with tractors or self-propelled machines was published as ASAE Standard S279, "*Lighting and Marking of Farm Equipment on Public Roads*" in the 1965 edition of Agricultural Engineers Yearbook. It is instructive to consider the purposes for which this 1965 edition of the standard was aimed:

> "1.1 To provide for lighting and marking of farm equipment for the purpose of promoting safety for the operator of the equipment and for the operators of other vehicles whenever such farm equipment is in operation, or is being transported, on a public road;
>
> 1.2 To provide manufacturers with a suitable guide for uniform practice in the industry; and
>
> 1.3 To assist regulatory bodies and educational groups in formulating uniform regulations and programs governing the operation or transport of farm equipment on public roads."

The S279 standard (1965 edition) distinguished between lighting and marking for daytime versus nighttime transport on roadways, as well as between what was required for equipment with and without electric lighting systems. Daytime transport of farm equipment on roads required equipment *with* electric lighting systems to have a safety lamp showing red to the rear and amber to the front mounted at the left rear of tractors, self-propelled machines, and mounted or towed implements. Equipment *without* an electric lighting system was to display a warning flag or other generally accepted emblem during daytime transport.

Numerous revisions and enhancements have occurred to S279 over the ensuing 40 years. Most revisions and enhancements occur in one year and are published the following year. The current version, S279.13 "*Lighting and Marking of Agricultural Equipment on Highways*" incorporates provisions for at least two red, rear-facing stop lamps on machines designed for travel at speeds over 25 mph (40 km/h) and optionally for slower transport design speeds. These stop lamps are illuminated by braking control activation and deceleration rate of the equipment. Stop lamps may be combined with tail

lamps or may be in addition to them, in which case they are placed at the left and right rear extremities and, if used to meet additional turn indicator provisions, must perform accordingly. However, if the machine is less than 4 feet (1.2 meters) wide, only one stop lamp is required. Any semi-mounted or towed implement designed for speeds over 25 mph (40 km/h), or any fully mounted implement that obscures the stop lamps on the propelling machine, must be fitted with stop lamps to take the place of those obscured. This is in addition to being fitted with lighting to take the place of any lamp on the propelling machine that is obscured. A detailed study of the history of the lighting and marking standard for agricultural equipment has been prepared by Murray Madsen (2008) from the University of Iowa.

ASAE Standard S318 "*Safety for Agricultural Field Equipment*" contains one section that specifically addresses tractor and machinery operation on highways. This section is shown below:

13 Travel on highways

13.1 Lighting and marking for agricultural field equipment shall conform to ANSI/ASAE S279 whenever such equipment is intended to operate or travel on public roads or highways.

13.1.1 The operator's manual for the unit shall instruct the operator to turn on flashing warning lights whenever traveling on a highway, except where such use is prohibited by law.

13.2 Agricultural tractors and self-propelled machines with operator enclosures (cabs) shall have at least one rear-view mirror to permit the operator to see the highway behind the machine.

13.3 Hitch pins and other hitching devices shall be provided with a retainer to prevent unintentional unhitching.

13.4 Components that are retracted to decrease the width for highway transport shall have means to positively secure those components during highway transport. One or more types of locking systems may be used. Examples of locking systems are hydraulic cylinder locks and folding over-center.

13.5 Provisions shall be made for the use of auxiliary attaching systems per ANSI/ASAE S338 on towing machines and on equipment where expected uses include towing on highways by single point attachment.

13.6 For towed or semi-mounted implements, instructions in the operator's manual and sign(s) on the machine shall specify a maximum transport speed.

3.2.7 LICENSED DRIVERS

The specific concern with this issue is youthful drivers of farm equipment on public roads, although it is possible for other unlicensed drivers to operate agricultural equipment on the same roads as motor vehicle traffic. One example of this is with Anabaptist populations who work for hire on non-Anabaptist agricultural operations and have access to tractors. Nevertheless, the greatest concern is with youth under the age of 16 who may not legally operate a motor vehicle on a public road but who may legally operate agricultural equipment on the same road. Only one study was found that addresses the issue in any detail. Doty and Marlenga (2006) published a study that

reviewed state laws regulating youth who operate farm tractors on highways in the United States.

The impetus for this study was the 1994-enacted legislation in Wisconsin (becoming effective in 1997) requiring youth who operate tractors on highways to complete a tractor and machinery certification course. Doty and Marlenga (2006) systematically searched state vehicle codes for references to driver's licensing and other requirements for youth and adults operating farm tractors on highways. As with most studies of this nature, other researchers that try to replicate such a study may come up with different results and conclusions because of imprecise terminology within statutes, and interpretations of those statues by state officials. The Doty and Marlenga (2006) findings included:

- 14 states have some type of restriction for youth operating farm tractors on highways.
- Six of these states require a driver's license in order to operate farm tractors on highways regardless of driver's age.
- The remaining eight states have legislation that includes specific provisions regarding youth driving farm tractors or other agricultural equipment on highways. The exact provisions vary by state but include age, location, or time of day restrictions, as well as educational components.
- Four of these states require youth tractor operators to obtain a special agricultural permit, license or certification.

Since 1968, the U.S. Department of Labor (USDOL, 1968) has declared many agricultural tasks to be hazardous for youth under the age of 16. This regulation is commonly referred to as Agricultural Hazardous Occupations Orders (AgHO). With certain exemptions, employment of youth under 16 for these hazardous tasks is illegal. The law does not apply to youth under 16 who are employed, either with or without compensation, by their parents or legal guardians. As part of this declaration, a procedure was established by the Department of Labor so that youths 14 and 15 years of age could be exempted from certain portions of the law. This exemption includes agricultural tractors and specific types of farm machinery. More specifically, the exemption states that with successful completion of a 10- hour training program, 14 and 15 year-old youths can be employed to operate a tractor of over 20 PTO horsepower (15 kW), or connect or disconnect an implement or any of its parts to or from such a tractor. This exemption assumes that youth are already familiar with normal working hazards in agriculture; if they are not a 4-hr orientation program to normal working hazards is required. Additionally, with successfully completing a 20-hour training program offered by 4-H and FFA, youths can be employed to operate specified farm machinery.

More important to this discussion is how the term "agriculture" is defined in this regulation. In the definitions section of this law, the term "agriculture" is defined to include: "farming in all its branches and among other things includes. . . preparation for market, delivery to market, delivery to storage or to market or to carriers for transportation to market." This statement allows a properly trained youth to haul produce and other products to markets, between farms, etc. As a rule, state motor vehicle regulations that are more restrictive than federal regulations take precedence over the federal regulations. For example, in the 14 states identified by Doty and Marlenga (2006) with laws regulating youth farm tractor operators on highways, youth may be prohibited

from operating farm tractors on highways even if they have been properly trained under the AgHOs. In the other states without any youth licensing restrictions, the AgHOs supports 14 and 15 year old youths operating tractors on public roads and, with higher speed tractors, would allow them to operate tractors at speeds upward of 35-40 mph (56-64 km/h).

4.0 HIGHER SPEED TRACTORS

4.1 PROBLEMS IDENTIFIED BY US:

- In the United States, farm tractors, self-propelled and towed equipment often fall outside road vehicle legislation requirements.
- Tractor speeds have increased in recent years. In order to protect other road users, tractors and towed equipment must be engineered to allow the driver to retain control of both the tractor and towed equipment under all conditions.
- Key safety-related systems that may be an issue at higher speeds include steering, brakes, suspension, tires, alignment, hitching components, tractor rollover protective structures (ROPS), SMV emblem, and the speed indicator symbol (SIS).

4.2 WHAT DO WE KNOW ABOUT THESE PROBLEMS?

4.2.1 TRACTOR SPEEDS.

Historically, the majority of tractors in the United States were designed to travel at a top speed of approximately 20 mph (30 km/h). These vehicles normally featured rigid rear axles and trunnion mounted front axles with full engineering standards available for design and manufacturing processes. In the 1980s European tractors, particularly those with 100 hp (75 kW), began to be designed with a top ground speed exceeding 25 mph (40 km/h). Physically, these tractors are similar to 20 mph (30 km/h) machines except in gearing and brakes. Tractor standards acknowledged their presence and were modified to incorporate appropriate braking standards. Tractors incorporating higher ratio gearing and suspension of their front axles were introduced in 1994; these tractors were able to travel 32 mph (50 km/h). In 2005 ASABE Standard S390, "*Definitions and Classifications of Agricultural Field Equipment*", was revised to include categories of ground speed. The standard, also approved by the American National Standards Institute (ANSI), divided agricultural field equipment into 5 ground speed classifications (Table 3) based on their nominal maximum ground speed in an original equipment configuration as designed and specified by the manufacturer. While there is no specific definition of "higher speed" tractor in this standard, for our purposes, when a tractor's highest speed is rated equal to or more than 25 mph (40 km/h), the tractor is considered as a higher speed tractor.

Table 3. Agricultural equipment ground speed classes

		Ground Speed (km/h)				
Agricultural Field Equipment Group	Symbol	25	40	50	65	>65
Agricultural tractor	ATR	ATR25	ATR40	ATR50	ATR65	ATR65 Plus
Towed implement	ATI	ATI25	ATI40	ATI50	ATI66	ATI65 Plus
Rear mounted implement	MER	Not Applicable				
Front mounted implement	MEF	Not Applicable				
Rear semi-mounted implement	SMR	SMR25	SMR40	SMR50	SMR65	SMR65 Plus
Front semi-mounted implement	SMF	SMF25	SMF44	SMF50	SMF65	SMF65 Plus
Self-propelled machine	SPM	SPM25	SPM40	SPM50	SPM65	SPM65 Plus
Bulk carrier/agricultural trailer	ABC	ABC25	ABC40	ABC50	ABC65	ABC65 Plus

Source: ASAE Standard 390.4 (2005)

A review of the Nebraska Tractor Test Summary reports shows that of over 500 tractors tested (Grisso, 2007), road gear speed of the tractors tested has increased in the

last five years (Figure 1). Currently between 40-45% of the tractors tested are equal to or exceed 25 mph (40 km/h). When compared to the tractors tested over the last 20 years to the last five years (Figure 2), there is an increase in tractors tested at speeds equal to or greater than 25 mph (40 km/h). The results indicate that tractors are available that can exceed 25 mph (40 km/h).

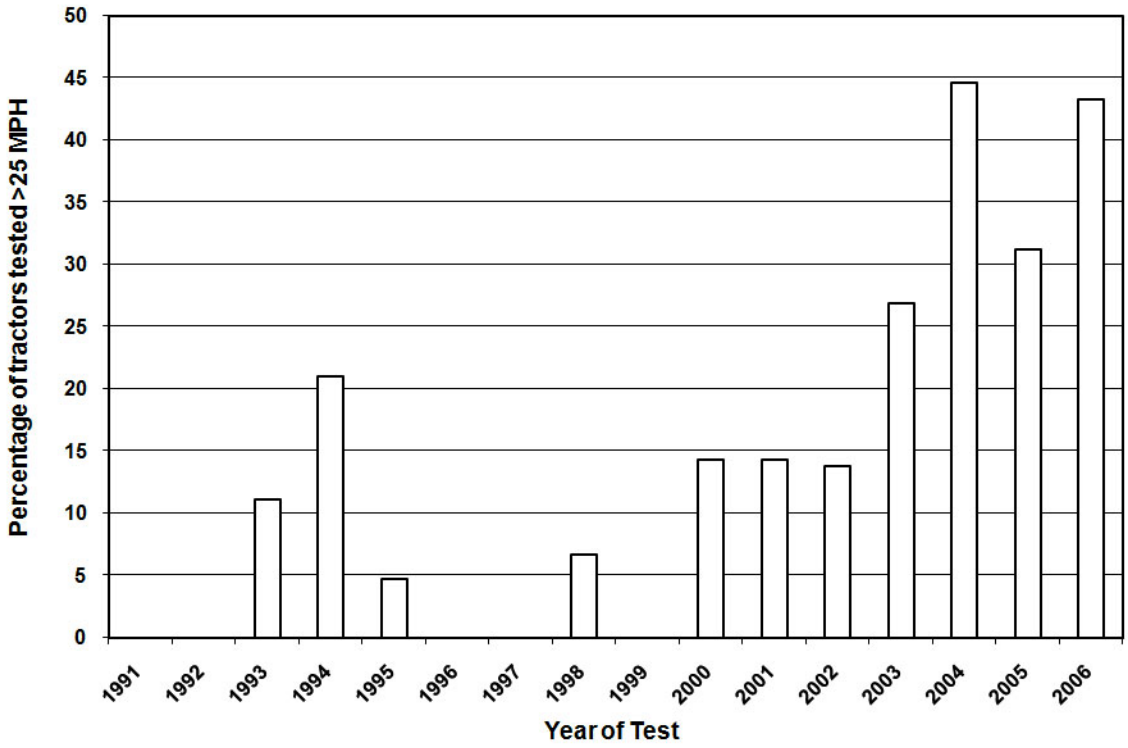

Figure 1. The frequency of the tractors tested by year that the high-gear allowed for travel speeds greater than or equal to 25 mph.

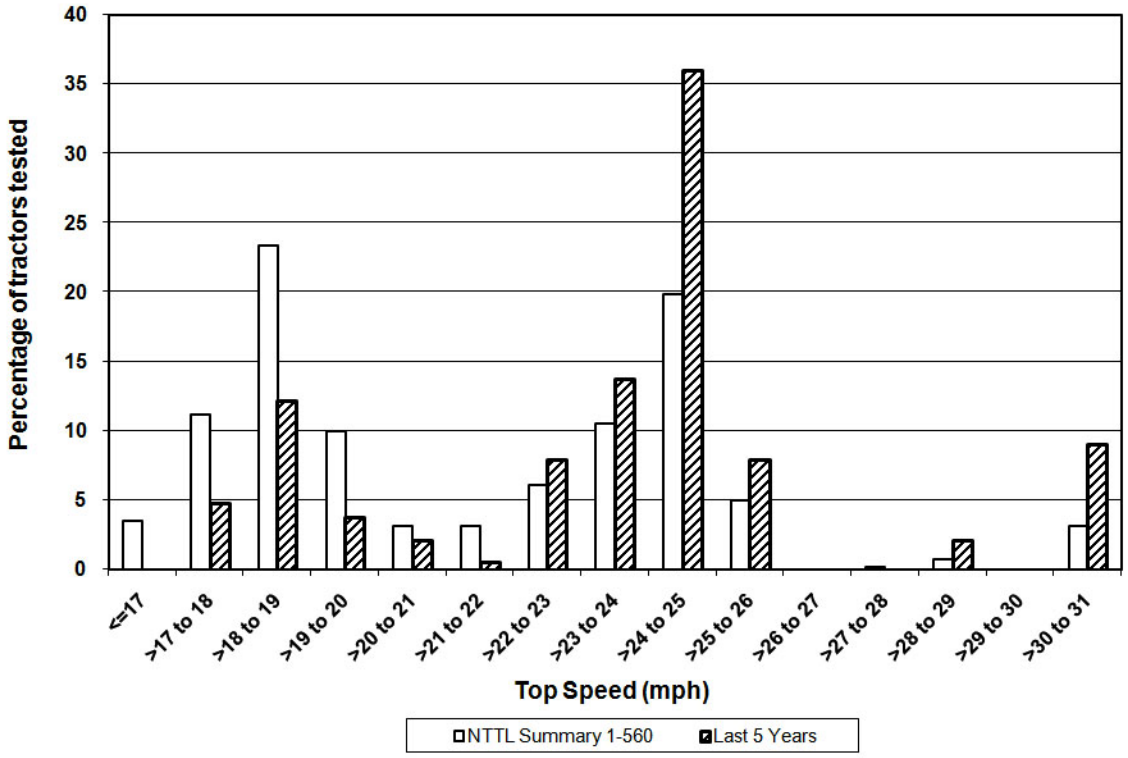

Figure 2. The percentage of tractor high gear speed for road transport tested over last 20 years and tested the last five years.

4.2.2 TRACTOR STEERING.

Historically, tractors have incorporated: a) pure mechanical steering; b) hydraulically assisted mechanical steering; and c) full hydrostatic steering systems. While many older tractors still in use have mechanical steering, most current tractors use hydrostatic steering. The characteristics of hydrostatic steering are:

- Low steer effort
- High steer torque
- Limited or no feedback from the road wheels to the steering wheel
- Limited or no self aligning ability, and
- Limited steering in the event of an engine or hydraulic failure.

Loss of steering during an engine failure has been a concern but tests show that during these situations, total malfunction of the steering system does not occur (Grisso, 2007). The driver is able to steer the tractor within a determinate radius and has time appropriate for stopping the tractor. Experience shows that hydraulic steering systems do not fail abruptly. In addition, some systems are self-aligning and are designed with sufficient hydraulic reserve for the driver to respond appropriately and maintain control of the tractor.

The response of the vehicle to input from the steering wheel is critical to vehicle feel and behavior. If the time is too short, the tractor will be sensitive to operate and require continuous correction to maintain it in a straight line. Conversely, if the time is too long, the tractor will be sluggish to respond and may create steering problems for the driver. In

the extreme case, if the driver first steers right and then rapidly left (as they would while driving a car), the driver may be turning the wheel left while, or even before, the vehicle has started to move right. Or the driver may continue turning right, resulting in turning too far right. In either case the steering wheel becomes out of phase with the motion of the road wheels and in attempting to correct this, the steering column can appear to have elastic properties. In practice, the target response time to develop maximum cornering force is between 0.6 and 0.8 seconds.

4.2.3 TRACTOR BRAKING.

Fundamentally, brakes serve the function of reducing vehicle kinetic energy by conversion into heat energy. As a function of the square of vehicle speed, kinetic energy increases rapidly. For example, a tractor traveling at 50 mph (80 kph) dissipates approximately seven times the energy for braking than a tractor traveling at 20 mph (30 kph). This situation is exacerbated by the legal requirement for faster moving vehicles to decelerate at higher rates. For example, 20 mph (30 kph) tractors have historically been required to have braking systems capable of deceleration at 9.3 ft/s^2 (2.8 m/s^2). When tractors reach a speed of 30 mph (50 kph), they are required to decelerate at a rate of 16.4 ft/s^2 (5.0 m/s^2), which is the same as the trucking industry.

With the combination of higher energy level and more rapid deceleration, brake systems with excellent heat dissipation characteristics are required. Conventional tractors have normally relied on either dry or oil immersed disc brakes incorporated within the tractor rear axle. The oil used is common with that used for axle lubrication, gearbox lubrication and as an external hydraulic oil supply to implements. Contamination of this oil with brake lining debris can lead to serious functional problems within the tractor hydraulic or transmission systems. Breakdown of oil lubrication properties can also occur if the oil is subjected to high temperatures leading to impaired durability of components.

The weight distribution and large rear tires of conventional tractors have enabled tractors to generate sufficient braking effort from their rear wheels alone; typically such tractors have no front brakes fitted. The move to 25 mph (40 kph) tractors in Europe has coincided with the almost universal acceptance of front wheel assist driven axles. This has given manufacturers the opportunity to engage the front axle drive while braking. This technology has also been carried into the 32 mph (50 kph) tractor models, with the addition of incorporating some form of disc brakes onto the front drive system to assist the braking effort.

According to the ANSI/ASAE Standard, S365.8, "*Braking System Test Procedures and Braking Performance Criteria for Agricultural Field Equipment*," the braking system requirements for agricultural trailers and towed agricultural machines are broken into two areas: one concerning towed equipment without brakes and the second with brakes:

1. For towed equipment WITHOUT brakes, the following information shall be provided: Do not tow equipment that does not have brakes:
   - at speeds over 20 mph (32 kph); or
   - at speeds above that recommended by the manufacturer; or
   - that, when fully loaded, has a mass (weight) over 3300 lb (1.5 t) and more than 1.5 times the mass (weight) of the towing unit.

2. For towed equipment WITH brakes, the following information shall be provided: Do not tow equipment that has brakes:
   - at speeds over 32 mph (50 kph); or
   - at speeds above that recommended by the manufacturer; or
   - that, when fully loaded, has a mass (weight) more than 4.5 times the mass (weight) of the towing unit.
   - at speeds over 25 mph (40 kph), when fully loaded has a mass (weight) more than 3.0 times the mass (weight) of the towing unit.

4.2.4 TRACTOR AXLE SUSPENSION.

United States tractors are not traditionally manufactured with suspension systems. However, a fully suspended chassis, i.e., a suspension system for both front and rear axles, may improve handling at all speeds. On a conventional tractor without suspension, the weight can come off the wheels when going over a bump, giving minimal traction when brakes are applied. The weight is also transferred forward onto the front axle, but most of the braking power is in the rear axle. These factors combine to limit the braking ability of the conventional tractor. With a full suspension, as the wheels go over bumps in the road the wheel and axle are able to move up out of the way of the rough terrain while the weight distribution remains similar. With a full suspension the wheels are more apt to stay in contact with the ground which will maximize the traction coefficient of the wheels during braking and under traction. For example, a full chassis construction allows the mass of the machine to 'float over' the full suspension while the axles follow the contours of the ground.

In general, the benefits of a full suspension system can be summarized as follows:

- Greater ride comfort and isolation from whole body vibration, both in the field and on the road.
- Better control of the vehicle by the driver through minimized ground force variations of the wheels.
- Better handling characteristics of the vehicle for safer use on the road, particularly at higher speeds
- Increased traction through constant ground force at the wheels.
- Potential for greater travel speeds made possible by minimized body accelerations.

The requirements for an optimal full suspension system on a tractor, whether higher speed or conventional, are:

- Tires kept such that the force that they exert on the ground surface remains nearly constant.
- Tractors able to experience large variation in loading either within the wheelbase (as in a loaded truck) or cantilevered at the rear or front of the vehicle when carrying mounted implements.
- During high power and high draft operations, power is transmitted through the drive wheels using low speed and high torque. This torque has to be reacted through the axle location mechanism with no vertical component reaction.
- Significant axle travel to avoid generating high ground forces when addressing bumps
- Predictable and controllable cornering characteristics are most easily achieved with equal tire sizes on both front and rear axles.

4.2.5 TRACTOR/TOWED EQUIPMENT TIRES.

Road transport is one of the extreme uses for an agricultural tire because a tire's worst enemy besides the hard pavement is heat. The recommended pressure not only depends on tire load (carried by the axle) but will depend on maximum speed. Different load/inflation tables are developed for the maximum speed of the machine. Tire data books list weight capacities and recommended air pressures along with maximum travel speeds.

According to the ANSI/ASAE Standard, S430.1, "*Agricultural Equipment Tire Loading and Inflation Pressures*," agricultural type tires are not designed for highway vehicle use or to operate at speeds in excess of 25 mph (40 km/h) except for the F1 tires designated as highway use. For agricultural tractor tires, according to SAE J709, similar designations are warranted for higher speed travel.

4.2.6 ROPS ON HIGHER SPEED TRACTORS.

The rollover protective structure (ROPS), as described in the Society of Automotive Engineers (SAE) Standard J2194 "*Roll-Over Protective Structures (ROPS) for Wheeled Agricultural Tractors"*, is a protective structure designed to minimize the frequency and severity of operator injury resulting from accidental tractor overturn. ROPS are designed to absorb energy resulting from the impact of the tractor with the ground surface during a tractor overturn. The intent of the standard and the testing procedures, according to SAE J67 "*Overhead Protection for Agricultural Tractors—Test Procedures and Performance Requirements*" is to protect the operator during field operations and not for vehicle crashes. The current ROPS test standard limits tractor test speeds to 3-5 mph (5-8 km/h) for rear rollover, and a minimum velocity of 10 mph (16 km/h) for side rollover.

Liu and Ayers (2007) reported on the following concerns for ROPS on a higher speed tractor: 1) how much more energy should a ROPS for a higher speed tractor absorb; 2) how different are the impacting forces that the higher speed tractor will generate if it overturns; 3) how the forward speed influences the energy absorbed by the ROPS in the longitudinal and vertical directions; and 4) if the current criteria for the ROPS test is compatible or strong enough for the ROPS of the higher speed tractor. They did not address safety trade-offs that a stronger ROPS may introduce, such as lowered operator visibility (especially when entering roadways), the potential of decreased stability from a higher center of mass, or the increased risk to other road users from higher mass tractors.

4.2.7 DRAWBAR HITCH.

The North American drawbar hitch is a uniquely designed hitch and may not be adequate for higher speed tractors. The drawbar and hitch pin configuration may give too much flexibility for stable control at higher speed. A ball hitch (80 mm being considered as a standard) would be an effective solution but the location of the ball relative to the tractor rear axle is critical. The farther forward the hitch is connected, the more stable the towed equipment will be during road operation. Unfortunately, moving the hitching location forward decreases the turning radius, which limits operations during fieldwork.

5.0 TRANSPORTATION OF WORKERS ON PUBLIC ROADWAYS WITH FARM EQUIPMENT

5.1 PROBLEMS IDENTIFIED BY US:

- The majority of the farm equipment, including tractors, combines, and other self propelled machinery, are designed with only one seat, which is for the operator.
- Towed equipment on public roadways, including wagons and trailers, do not have safe seating accommodations for either an operator or other persons on them.
- Lighting and marking of animal-drawn vehicles on public roadways (e.g. Anabaptist farming communities) may not be adequate to warn motorists of the slow speeds these vehicles are moving, increasing the risk of collisions.
- There are no clear regulations preventing adults, employees or farm family members from being extra riders on farm equipment on roadways, or being transported on towed equipment on roadways.

5.2 WHAT DO WE KNOW ABOUT THESE PROBLEMS?

Farm tractors and most self-propelled equipment were traditionally manufactured with a seat for only the operator. Nevertheless, carrying another person on the tractor or self-propelled machine, popularly known as an “extra rider”, is a common practice among farmers. Reasons for extra riders on tractors and self-propelled machines includes saving diagnosis, performance and monitoring time, convenience, work assistance, training, information exchange, and child supervision. Common unsafe extra rider locations on tractors are the drawbar, side links of 3-point hitches, rear axle housing, rear wheel fenders, and the operator platform. Most towed farm machines excepting select planters and bean buggies, for example, are not manufactured with any designated safe place for riders though this practice, too, is common for the same reasons as people ride extra on tractors. The tongue of a towed implement, inside or on the bed of trailers or wagons, and on top of crops and produce are common locations for these riders. An example of an extra rider on a self-propelled machine would be a person riding in the bucket of a skid steer loader. Extra rider injury incidents occur while the machine is being operated in fields, around farmsteads, and on public roadways.

In 1993, AGCO Corporation became the first United States tractor manufacturer to provide a passenger seat on some of their larger tractor models sold in the United States (Metcalf, 1993). For example, AGCO Allis tractors between 133 to 191 horsepower and AGCO White tractors between 121 to 192 horsepower came with a second seat in addition to the operator seat as standard equipment. The passenger seat was provided only on tractors with enclosed ROPS cabs and a seat belt for the passenger was provided. Other manufacturers soon followed suit and in 2000, ASAE adopted ANSI/ASAE S574, *Instructional Seat for Agricultural Equipment*, as a standard. As noted by the standard title, by the time the standard was adopted the preferred term was “instructional seat”. The standard stipulates that the purpose of the instructional seat is for limited use by a trainer or trainee inside a closed cab on tractors and self-propelled agricultural equipment, and that it is not intended or designed for use by children.

There are limited statistics on the number of deaths or injuries associated with the transportation of workers on farm equipment or towed implements on public roadways. The specific concerns with having extra riders on such equipment on public roads are the

speed of the equipment and the unprotected nature of the extra rider in the event of a vehicle crash, whether on the prime mover or riding a towed implement such as a trailer.

Most studies examining extra riders on farm equipment have focused on youth. Mason and Earle-Richardson (2002) suggested youth falling from farm tractors and other farm equipment (presumably as extra riders) were a major cause of death for youth on New York farms. Studies of farm operators suggest a willingness to allow extra riders on farm tractors, especially those over the age of 14 years of age (Aherin and Todd, 1989; Ambe et al., 1995), but neither study looked at such behaviors specifically on public roads, or the work-relatedness of such behaviors. Similarly, in a study of farm youth in Kentucky, Browning et al. (2001) found that 54% of the youth between the ages of 10 and 18 years reported being an extra rider on a farm tractor in the last year. Again, there was no specific information if these youth were extra riders while on public roadways, or if such activities were work-related. The Migrant and Seasonal Farm Worker Protection Act (MSPA) requires farm operators and farm labor contractors to provide a minimum level of protection when transporting farm workers to and from farming operations for work (29 CFR500, 1983). This includes providing a designated seat for each worker in a registered, inspected passenger vehicle with one exception: when transporting farm workers to work areas within ten miles of the farm center, where the transport is primarily (but not exclusively) on farm roads, and where the travel begins and ends on the farm's property. The MSPA does not permit the transport of farm workers on farm machinery, other than the machine operator. The MSPA does not apply to farm family members.

There are numerous fact sheets developed by a variety of safety specialists within the USDA extension service warning farm operators about the risks of having extra riders on farm equipment (especially farm tractors), or towed implements (Karsky and Jaussi, 1998; Lehtola and Brown, 2001; Murphy and Steel ,1995; Schwab, 1996).

6.0 SUGGESTIONS FOR THE FUTURE

Based on the work presented in this report the committee has developed several suggestions to help guide future research, standards setting, policy and education/outreach among federal, state and local levels of government and production agriculture organizations. All of these entities share a responsibility to help motor vehicles and agricultural machinery and equipment mix safely on public roads.

Research is needed to:

1. Develop criteria to better describe characteristics of crashes between motor vehicles and agricultural equipment using standard reporting terminology. This would include developing model definitions, methods, and data collection instruments. Examples of standard data elements would include:
    a. Road and visibility conditions
    b. Ages of victims
    c. Vehicle and agricultural equipment features (including type and size of equipment, whether machine or animal-drawn, and compliance with current lighting and marking, braking, and other related standards)
    d. Environmental conditions (e.g., time of day, rain, icy)
    e. Driving actions of motorists and equipment operators
    f. Whether victim(s) was operator or rider
    g. Alcohol and/or drug abuse
2. Assess the understandability, effectiveness, and best use practices of lighting and marking of agricultural equipment on public roadways. This should include both urban and rural motorists and would focus on topics such as:
    a. Slow moving vehicle (SMV) and Speed Indicator Symbol (SIS) emblems
    b. Animal-drawn buggies, wagons and implements, including culturally acceptable lighting and marking systems for Anabaptist populations
3. Improve engineered systems for higher speed tractors, self-propelled machines and towed equipment. This would include such topics as:
    a. braking systems
    b. suspension systems
    c. steering controls
    d. hitching/attachment mechanisms
    e. proximity sensors to motor vehicles
    f. tires
    g. ROPS
4. Examine the existence and consistency of farm equipment roadway safety information in driver's education programs across the United States.
5. Expand behavioral studies on allowing extra riders on farm equipment to include adults, and such factors as extra riders on public roads for work-related purposes.
6. Determine the effects of graduated licensing for youth to operate agricultural equipment on public roads, including higher speed tractors and self-propelled machines.
7. Examine impacts and implications of county and state land use policies regarding operation of agricultural equipment on public roadways. This would include topics such as:

a. Risks of crashes with motor vehicles
b. Exclusions and exemptions from road traffic regulations and restrictions
c. Transportation of agricultural hazardous materials on rural public roads
d. Economic issues and costs associated with heavy agricultural loads on rural public roads

Engineering design standards should:

1. Better connected to research findings.
2. Have better representation during their development by researchers and end-users.
3. Be used to incorporate automatic and passive protection for drivers and riders of agricultural equipment during public road use.
4. Be continually reviewed for the possibility of adoption of new technologies into design standards and practices.

Safety education programs are need to:

1. Educate both the public and farmers on:
    a. Best practices for operating agricultural equipment on public roads.
    b. Approaching slow moving vehicles on public roads, including the purpose and use of the SMV and SIS emblems.
    c. The effects of exclusions and exemptions from road traffic regulations and restrictions.
2. Work with local and state law enforcement agencies to increase awareness of county and state traffic laws related to farm equipment among law enforcement officers.
3. Encourage Amish buggy manufacturers to utilize marking and lighting systems and components that meet current ASABE, SAE, and DOT standards.

Policy is needed to:

1. Promote the purpose and use of the SMV and SIS emblems in every state's driver's license manual and driver's education program.
2. Encourage a more comprehensive Uniform Vehicle Code to be developed and adopted nationally and by states. This new code should better address modern types and uses of agricultural equipment on public roads. Topics that should be addressed include:
    a. Registration of farm equipment for use on public roads
    b. Qualifications and training for operating agricultural equipment on public roads
    c. Extra riders on farm equipment, including on tractors, self-propelled machines and towed equipment
    d. Animal-drawn buggies, wagons and equipment
3. Provide for a consistent source of funding for research into hazards, risks and best safety practices for operating agricultural equipment on public roads.
4. Encourage land-use policies by state and local governments to better manage the interaction of farming and non-farming uses of public roadways in their jurisdiction.
5. Encourage stricter enforcement by local and state police of SMV emblem misuse.

7.0 REFERENCES

Abend E, Hallman E. 1995. Slow-moving Vehicle Emblems. Fact Sheet. Department of Agricultural and Biological Engineering, Cornell University, Ithaca, NY.

Abrams BS. 1990. Roadway lighting, killer roads and the older driver. Presented before the "Lamplighter Section" of the Illuminating Engineering Society of North America. Printed by the Institute of Vehicular Safety, Columbus, Ohio. January.

Abrams BS. 1993. Human factors/night visibility. Published lectures for special problems in traffic accident reconstruction. Institute of Police Technology and Management, University of North Florida, Jacksonville, FL. April.

Aherin RA, Todd CM. 1989. Accident risk taking behavior and injury experience of farm youth. Paper No. 89-5530. St. Joseph, MI: ASAE.

Ambe F. 1994. Aged tractor operator exposure characteristics, injury incident experience, and condition of safety features on Pennsylvania farm tractors. PhD Dissertation. The Pennsylvania State University, University Park, PA.

Ambe F, Bruening TH, Murphy DJ. 1995. Tractor operator's perceptions of farm tractor safety issues and implications to agricultural and extension education. *Jour. Ag. Ed.* 35(4): 67-73.

Association of Equipment Manufacturers. About us. Available at http://www.aem.org/. Accessed December 2007.

American Society of Agricultural and Biological Engineers. Agricultural Engineers Yearbook (1954-1983); ASAE Standards (1984-2005); ASABE Standards (2006-present). St. Joseph, MI: ASABE. Standards cited:

1954 – S213 Safety Lighting for Combinations of Farm Tractors and Implements

1964 – S279 Lighting and Marking of Farm Equipment on Public Roads

1965 - S279.1 Lighting and Marking of Farm Equipment on Public Roads

2006 - S279.13 Lighting and Marking of Farm Equipment on Public Roads

1964 – R276 Slow Moving Vehicle Identification Emblem (SMV Emblem)

1997 - S276.5 Slow Moving Vehicle Identification Emblem (SMV Emblem)

2005 – S276.6 Slow Moving Vehicle Identification Emblem (SMV Emblem)

1994 - S430.1 Agricultural Equipment Tire Loading and Inflation Pressures

2000 – S574 Instructional Seat for Agricultural Equipment

2005 - S390 Definitions and Classifications of Agricultural Field Equipment

2007 - S390.4 Definitions and Classifications of Agricultural Field Equipment.

2005 - S584 Agricultural Equipment: Speed Identification Symbol (SIS).

2006 - S584.1 Agricultural Equipment: Speed Identification Symbol (SIS).

2006 – S318.16 Safety for Agricultural Field Equipment

2007 - S365.8 Braking System Test Procedures and Braking Performance Criteria for Agricultural Field Equipment

American Society of Agricultural and Biological Engineers. 2007. Title page to online standards. Available at http://asae.frymulti.com/. Accessed December 2007.

American Traffic Safety Services Association, The. 2008. Toward Zero Deaths: A Vision for Safer Roads in America. Fredericksburg, VA: The American Traffic Safety Services Association. 31 pp.

Barber AB. 1927. Making our traffic laws uniform. *Annals Am Acad Pol Soc Sci* 133: 128-330

Baker SP, O'Neill B, Ginsburg MJ, Li G. 1992. The Injury Fact Book. Second Edition. NY: Oxford University Press.

Baker SP, Whitfield RA, O'Neill B. 1987. Geographic variations in mortality from motor vehicle crashes. *N England J Med* 316: 1384-1387.

Becker WJ. 1991. Analysis of highway safety laws for agricultural vehicles, equipment and personnel. National Institute for Farm Safety, 1991 Summer Conference, Jackson, MI.

Becker, WJ. 1991. Farm equipment on the highway. Fact Sheet AE-87, Florida Cooperative Extension Service, University of Florida, Gainesville, FL.

Browning SR, Westneat SC, Szeluga R. 2001. Tractor driving among Kentucky farm youth: results from the Farm Family Health and Hazard Surveillance project. *JASH* 7(3):155-167.

Cedarquist S. Director of Standards & Technical Activities, American Society of Agricultural and Biological Engineering. Personal conversation, December 2007.

Code of Federal Regulations. 1983. Title 29 Labor, Chapter V, Part 500 Migrant and Seasonal Agricultural Worker Protection, Subpart D: Motor Vehicle Safety and Insurance for Transportation of Migrant and Seasonal Agricultural Workers, Housing Safety and Health for Migrant Workers. Available at http://www.dol.gov/dol/allcfr/ESA/Title_29/Part_500/toc.htm. Accessed May, 2008.

Committee on Agricultural Safety and Health Research and Extension. 2003. National land grant research and extension agenda for agricultural safety and health. Iowa State University, Reference No. EDC-292. Ames, Iowa: Iowa State University. 18 pp. Accessible at http://www.tmvc.iastate.edu/NCR197/.

Costello TM, Schulman MD, Luginbuhl RC. 2003. Understanding the public health impacts of farm vehicle public road crashes in North Carolina. *J Agric Saf Health* 9(1): 19−32.

Costello TM, Schulman MD, Mitchell RE. 2008. Risk factors for a farm vehicle public road crash. *Accid Anal Prev* doi.10.1016/j.app.2008.08.029 (in press).

Doty BC, Marlenga B. 2006. A summary of state laws regulating youth operating farm tractors on highways. *J Agric Saf Health* 12(1): 51-58.

Eberhardt MS, Ingram DD, Makuc DM. 2001. Urban and Rural Health Chartroom. Health, United States, 2001. Hyattsville, MD: National Center for Health Statistics.

Eicher LC, Wood RK, Bean TL, Carpenter TG, Holmes RG. 1995. Grid development for state codes regarding the lighting and marking of agricultural equipment on roads. *App Eng Agric* 11(1): 17-23.

Freeman SA, Schwab CV, Jiang Q. 2008. Quantifying stressors among Iowa farmers. *J Agric Saf Health* 14(4): 431-439.

Garvey, P.M. 2003. Motorist comprehension of the Slow–Moving Vehicle (SMV) emblem. *JASH* 9(2):159-169.

Gerberich SG, Robertson LS, Gibson RW, Reiner C. 1996. An epidemiological study of roadway fatalities related to farm vehicles: United States, 1988-1993. *J Occup Environ Med* 38(11): 1135-40.

Gilliam JM, Jones PJ, Field WE, Kraybill DB, Scott SE. 2007. Farm-Related Injuries Among Old Order Anabaptist Children: Developing a Baseline from Which to Formulate and Assess Future Prevention Strategies. *J Agromed*, Vol. 12(3).

Glascock LA, Bean TL, Wood RL, Carpenter TG, Eicher LC and Holmes RG. 1995. State codes for lighting and marking of agricultural equipment. *J. Agric Saf Health 1(1): 17-26.*

Graham JD. Injuries from traffic crashes: meeting the challenge. 1993. *Annual Rev Pub Health* 13: 515-43.

Grisso R. 2007. Personal communications with Earle Morton, AGCO Corporation, September 25, 2007.

Grisso RD. 2008. Tractor Database from Test Reports. Available at: http://filebox.vt.edu/users/rgrisso/Pres/Nebdata.htm.

Hanna HM, Schwab CV, Lehtola CJ, Steffen RW. 1997. Evaluation of tractor and grain wagon safety marking at selected commercial Iowa grain elevators. *J Ag Saf Health* 3(2): 91-100

Harkness KA. 1963. Fluorescent-reflectorized triangular emblem to identify slow moving vehicles. Agricultural Engineering, July. St. Joseph, MI: American Society of Agricultural Engineers.

Harkness KA, Stuckey WE. 1962. Problems Associated with Identifying Slow Moving Vehicles Operated on Highways. Proceedings, Invitational Safety Seminar, Institute of Agricultural Medicine, State University of Iowa, October 17-18.

Hostetler JA. 1993. Amish Society. Fourth Edition, 1993. The John Hopkins University Press, Baltimore, MD.

Hughes R, Rodgman E. 2000. Crashes involving farm tractors and other farm vehicles/equipment in North Carolina, 1995-1999. Report prepared for Commercial Motor Vehicle Enforcement Section, North Carolina Division of Motor Vehicles. Chapel Hill, NC: University of North Carolina, Highway Safety Research Center.

Karlaftis MG, Golias I. Effects of road geometry and traffic volumes on rural roadway accident rates. *Acc Anal Prev* 34: 357-365.

Karsky T, Jaussi AK. 1998. Highway transport of agricultural equipment: preventing public road accidents. Pacific Northwest Extension Publication PNW 512. Moscow, ID: University of Idaho.

Kraybill DB, Olshan MA. 1994. The Amish Struggle with Modernity, University Press of New England, Hanover, NH.

Lehtola C. 2007. Slow to catch on to the slow-moving vehicle emblem. *J Agric Saf Health* 13(1): 5-7.

Lehtola C, Brown CM. 2001. When two's a crowd: dangers of extra riders on tractors. Florida Cooperative Extension Service Document AE300. Gainesville, FL: University of Florida.

Lehtola CJ, Marley SJ, Melvin SW. 1994. A study of five years of tractor-related fatalities in Iowa. *Appl Eng Agr* 10(5):627-32.

Liu J, Ayers PD. 2007. Impact of Changes in ROPS Standards, Regulations and Technology on Future Tractor ROPS Availability. Report prepared for "National Tractor Safety Initiative.

Luginbuhl RC, Jones VC, Langley RL. 2003. Farmers' perceptions and concerns: the risks of driving farm vehicles on rural roadways in North Carolina. *J Agric Saf Health* 9(4): 327-349.

Madsen, M. 2008. Farm equipment lightning. Unpublished document, available upon request. University of Iowa, Iowa City, IA.

Mason C, Earle-Richardson G. 2002. New York state child agricultural injuries: how often is maturity a potential contributing factor? *AJIM* S2: 36-42.

McClure B, Lamp BJ. 1961. An Analysis of 212 Fatal Ohio Farm Tractor Accidents. ASAE Paper No. 61-129. St. Joseph, MI: American Society of Agricultural Engineers.

McFarland DT. 1965. Survey of Lighting and Marking Regulations July-August 1964 (Farm Tractors, Self-propelled Equipment, and Implements of Husbandry). Farm Department Report, National Safety Council, Chicago, IL.

Metcalf J. 1993. AGCO Corporation offers the first U.S.-made tractor passenger seat. Wisconsin State Farmer, December 17.

Michigan Farm Bureau. 1999. Vehicle farm equipment crashes drop, but roads are still dangerous. *Michigan Farm News*. Available at www.michiganfarm bureau.com/publications/farmnews/mfn04301999/vehicle.htm.

Murphy DJ, Steel S. 1995. Extra riders on farm equipment. Pennsylvania Cooperative Extension Service Fact Sheet E-40. University Park, PA: The Pennsylvania State University.

Murphy DJ, Kiernan NE, Hard DL, Landsittel D. 1998. The Pennsylvania central region farm safety pilot project: part I—rationale and baseline results. *J Agric Saf Health*, 4(1): 25-41.

National Committee on Uniform Traffic Laws and Ordinances. 2000. Uniform Vehicle Code 2000. Washington, DC: National Committee on Uniform Traffic Laws and Ordinances.

National Highway Traffic Safety Administration. 2008. Traffic Safety Facts 2007: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System. DOT HS 811 017. U.S. Department of Transportation, Washington, D.C.

National Highway Traffic Safety Administration. 2007. Traffic Safety Facts 2006 [early edition]: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System. DOT HS 810 818. U.S. Department of Transportation, Washington, D.C.

National Highway Traffic Safety Administration. 2006. Traffic Safety Facts 2005: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System. DOT HS 810 631. U.S. Department of Transportation, Washington, D.C.

National Highway Traffic Safety Administration. 2005. Traffic Safety Facts 2004: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System. DOT HS 809 919. U.S. Department of Transportation, Washington, D.C.

Ohio Revised Code. Ann. §4513.11. 2007. Animal-drawn or slow-moving vehicles, lamps, reflectors and emblems.

Ottey AR, Fink C. 1990. Road travel tops lists of safety concerns. *Farm Journal*. 114(3): B-4.

Petrea C. 2004. Safe Movement of Farm Machinery on Public Roadways. University of Illinois. Retrieved May 14 2008 at http://www.age.uiuc.edu/agsafety/smfmpr.html.

Peek-Asa C, Sprince NL, Whittem PS, Falb SR, Madsen MD and Zwerling C. 2007. Characteristics of crashes with farm equipment that increase potential for injury. *J. Rural Health* 23(4):339-347.

Peek-Asa C, Zwerling C, Stallones L. 2004. *Am J Public Health* 94(10): 1689-1693.

Pratt SG. 2003. Work-related roadway crashes: challenges and opportunities for prevention. DHHS (NIOSH) Publication No. 2003-119. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Morgantown, WV.

Pinzke S, Lundqvist P. 2004. Slow-moving vehicles in Swedish traffic. *J Agric Saf Health* 10(2): 121-26.

Scott SE. 1981. Plain Buggies: Amish Mennonite, and Brethren Horse-drawn Transportation. Good Books, Intercourse, PA.

Society of Automotive Engineering. SAE Standards. Warrendale, PA: SAE. Standards cited:

1977 – E J709 Agricultural Tractor Tire Loadings, Torque Factors, and Inflation Pressures.

1970 – J167 Overhead Protection for Agricultural Tractors—Test Procedures and Performance.

1987 – J2194 Roll-Over Protective Structures (ROPS) for Wheeled Agricultural Tractors.

1988 – J1150 Terminology for Agricultural Equipment.

Schwab C. 1996. Extra riders mean extra dangers. Iowa Cooperative Extension Service Pub. No. PM-1518c. Ames, IA: Iowa State University.

Schwab C. 1997. A tractor collision story. Iowa Center for Agricultural Safety and Health, Summer Newsletter. University of Iowa, Iowa City, IA.

Schwab C, Miller L. 2004. Use SMV Emblems for Your Safety. Extension Publication No. PM1265j. Iowa State University, Ames, IA.

Schwab C, Miller L. 1995. Safety on Iowa Roads: Sharing the Road with Farm Vehicles. Extension Publication No. PM1629. Iowa State University, Ames, IA.

Tevis, C. 2008. *Successful Farming*, Mid-March. Des Moines, IA: Meredith Corporation.

U.S. Census Bureau. 1999. US Department of Commerce, Washington, DC.

U.S. DOL. 1968. Employment of minors between 14 and 16 years of age in economic opportunity programs. *Federal Register* Vol. 32(216).

U.S. DOT. 1971. Agricultural Tractor Safety on Public Roads and Farms. Washington, DC: U.S. Department of Transportation.

West D, May J. 1998. A safety survey of auctioned farm equipment. *J Agric Saf Health* 4(4): 245-253.

Zook L. 1993. "Slow-Moving Vehicles". In The Amish and the State, Kraybill DB (Editor). The John Hopkins University Press, Baltimore, MD.

8.0. COMMITTEE ON AGRICULTURAL SAFETY AND HEALTH RESEARCH AND EXTENSION

Robert Aherin, Ph.D.	University of Illinois
Connie Baggett, Ph.D.	Pennsylvania State University
Roberto Barbosa, Ph.D.	Louisiana State University
William Field, Ed.D	Purdue University
Bobby Grisso, Ph.D.	Virginia Tech
Dee Jepsen, Ph.D.	Ohio State University
Carol Lehtola, Ph.D.	University of Florida
Ronaldo Maghirang, Ph.D.	Kansas State University
Marshall Martin, Ph.D. **	Purdue University
Dennis Murphy, Ph.D. *	Pennsylvania State University
John Myers, M.S.	Centers for Disease Control/NIOSH
Larry Olsen, Ph.D.	Michigan State University
Fred Oehme, Ph.D., D.V.M.	Kansas State University
John Pickrell, Ph.D.	Kansas State University
Mark Purschwitz, Ph.D.	University of Kentucky
Glen Rains, Ph.D.	University of Georgia
Bradley Rein, M.S. ***	USDA-CSREES-PAS
Ron Schuler, Ph.D.	University of Wisconsin
Charles Schwab, Ph.D.	Iowa State University
John Shutske, Ph.D.	University of Minnesota
John Slocombe, Ph.D.	Kansas State University
Aaron Yoder, Ph.D.	Pennsylvania State University

**Chair*
***Administrative Advisor*
****CSREES Representative*