Understanding the Public Health Impacts of Farm Vehicle Public Road Crashes in North Carolina

T. M. Costello, M. D. Schulman, R. C. Luginbuhl

ABSTRACT. *Discussions with groups of North Carolina farmers identified farm vehicle public road safety as their primary occupational health and safety concern. Findings of a mail survey of North Carolina growers participating in a North Carolina Department of Labor migrant housing inspection program indicated that over 97% of them felt less safe on North Carolina public roads now (1999) than five years prior (1995), and over 79% currently (1999) felt unsafe transporting farm vehicles on North Carolina public roads. Using both primary and secondary data, we explore the context of farm vehicle public road crashes, identify contributing individual and environmental risk factors, and estimate the public health cost. Recommendations and suggestions for future farm vehicle public road safety research and interventions are proposed.*

Keywords. *Agriculture, Farm vehicle crashes, Florida, Iowa, Michigan, North Carolina, Public roads, Risk, Rural, Tourism, Urban.*

The purpose of this analysis is to understand the public health impacts that farm vehicle public road crashes have on drivers sharing North Carolina roads. The need for this analysis stemmed from the following:

- Historically, agriculture has played an important role in North Carolina, accounting for over 30% of the state's economy (NCSU, 1999), and North Carolina farmers use public roads for agricultural production and delivery of goods to the marketplace.
- Changes in North Carolina's population have affected how North Carolina public roads are being used.
- North Carolina farmers voiced that their greatest safety concern was driving farm vehicles on public roads, and they indicated that sharing public roads has become more dangerous over a five–year period from 1995–1999.

In this article, we explore the context of farm vehicle public road use and crashes in an effort to understand and address the public health concerns voiced by North Carolina farmers.

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Overview

The North Carolina Department of Labor (NCDOL) initiated the Gold Star growers program to recognize excellence in compliance by farmers with migrant farmworker housing regulations. This group of 1,357 North Carolina growers provides input to and feedback on agricultural health and safety programs. During regional Gold Star grower meetings in 1999, participants indicated that a crash involving their farm vehicles on North Carolina public roads was their greatest safety concern (NCDOL, 1999; Street, 2000). This concern about farm vehicle crashes on North Carolina public roads was supported by quantitative findings from a mail survey (n = 656, 49% response rate; n = 574 available for data analysis) among Gold Star growers (Costello et al., 2000; NCDOL, 2000). Over 97% of mail survey respondents reported they "felt less safe transporting farm vehicles on North Carolina public roads than five years prior" (1995–1999) (Costello et al., 2000; NCDOL, 2000). In addition, over 79% of respondents reported that, at the time of the survey in 1999, they felt "unsafe transporting their farm vehicles on North Carolina public roads" (Costello et al., 2000; NCDOL, 2000). However, five–year data (1995–1999) of the North Carolina Department of Motor Vehicles (NCDMV) on farm vehicle public road crashes (Hughes and Rodgman, 2000) show a declining trend in reported crashes for the same five–year period. In an effort to better understand why subjective perceptions and official statistics might differ, we used primary and secondary data sources to identify and describe North Carolina farm vehicle public road crash risk factors, and determine their public health impacts.

Methodology

Several data sources were used to complete our analysis of North Carolina farm vehicle public road crash risk factors. Primary data collected by the authors included: (1) small group discussions among Gold Star growers in four North Carolina counties (Rockingham, Guilford, Forsyth, and Stokes) conducted in February 1999 (NCDOL, 1999), and (2) a mail survey, conducted in fall/winter 1999, of growers registered with the NCDOL (Costello et al., 2000; NCDOL, 2000). Secondary data from publicly available resources included: (1) North Carolina Division of Motor Vehicles (NCDMV) farm vehicle public road crash reports (1995–1999) (Hughes and Rodgman, 2000), and (2) statistics obtained through a literature review focusing on public road safety, crash risk factors, and issues pertaining to sharing the road with farm vehicles.

The resulting farm vehicle public road safety profile for North Carolina was compared with three other states having a varied mix of urban versus rural development, as well as farmers, tourists, residents, and industry competing for use of public roads. The three states selected for comparison with North Carolina were Iowa, Michigan, and Florida. The selection of states was made based on availability of farm vehicle public road safety data and state characteristics. With regard to agriculture, Florida, Iowa, Michigan, and North Carolina are ranked among the top ten agricultural states in the U.S. (USDA, 2000). With regard to tourism, Florida is ranked fourth in the U.S. (USDOC, 1995). North Carolina is ranked 32nd, Iowa 39th, and Michigan 46th in the U.S. (USDOC, 1995). With regard to population density, Florida has the highest with 239.6 people per square mile. Michigan had the next highest population density (163.6 people per square mile), followed by North

Carolina with 136.1 people per square mile, and Iowa with 49.7 people per square mile (U.S. Census Bureau, 1999).

The following research questions directed our analysis and interpretation of the primary and secondary sources:

1. Why might North Carolina growers report increased concern for farm vehicle public road crashes, while NCDMV reported crashes decreased over the same five–year period (1995–1999)?
2. Regarding farm vehicle public road crashes, how does North Carolina compare with other key agricultural states?
3. What individual and environmental factors play roles in farm vehicle public road crashes?
4. What kinds of prevention measures are currently in place in North Carolina and other agricultural regions faced with this safety issue?

Definitions of Terms

Population density (100,000 inhabitants) was selected as the denominator for the farm vehicle public road crash impact estimate, in the absence of vehicle miles traveled (VMT) typically used. This decision to use population density as the crash rate denominator was based on the assumption that population density best reflects the impact of exposure to the risk of a public road crash between farm and non–farm vehicles sharing public roads, given available data. The use of a farm vehicle public road crash rate for analysis provided a context in which inter–state comparisons could be made and traffic exposure as an environmental variable could be included.

For law enforcement and transportation coding purposes, farm vehicles are defined as any self–propelled or towed equipment used in agricultural production (NCDOT, 1999). When coding farm vehicle public road crashes, North Carolina law enforcement officers at the scene have two coding options: “FT” for farm tractor (self–propelled farm vehicles that may or may not be towing other farm equipment), or “FE” for farm equipment (self–propelled or towed farm vehicles other than tractors, e.g., a combine, truck, pickup, or trailer) (NCDOT, 1999). There are also specific coding categories for trucks and pickups, separate from the two farm vehicle options. So, a farmer–driven pickup or truck that is involved in a crash is most likely not coded as a farm vehicle but rather as a pickup or truck (trucks are subcategorized by number of axles). The same is true for larger trucks used to haul livestock. The lack of specificity in the coding definitions and training procedures suggests a potential coding bias for farm vehicles that should be addressed in future studies and analyses.

Findings

North Carolina Farm Vehicle Public Road Crashes

North Carolina agriculture accounts for approximately 30% of the state’s revenues and employs approximately 29% of the state’s workforce (NCSU, 1999). North Carolina farmers use public roads in the process of moving from field to field, taking products to market, and securing supplies. This requires North Carolina farmers to share the public road with a wide variety of other vehicles.

Over a 20–year period (1980–1999), annual state population growth rates as high as 15% (NCOSPL, 1997, 2000) have resulted in approximately two million new residents using North Carolina public roads as drivers or passengers. More than one million of those residents have arrived in the last ten years (NCOSPL, 1997, 2000).

In certain areas of North Carolina, the percentage population growth is higher than the annual ten–year (1990–1999) state average of 15% (NCOSPL, 2000). For example, population growth in Chatham (21.3%), Johnston (37.9%), Nash (16.2%), Pitt (17.9%), and Wake (38.9%) counties are above the 15% state average. These counties are major agricultural producers, in particular for tobacco, sweet potatoes, cotton, and livestock (USDA, 2000). Population growth, combined with the existing agricultural activity, has caused increased competition for public road use.

In addition to the increased number of new residents and businesses, North Carolina's tourist industry is growing in importance, adding to public road traffic, especially during peak spring/summer planting and summer/fall harvesting periods (NCDOC, 2001). North Carolina is known for its beaches in the east and its mountains in the west. Much of North Carolina's industrial base is located in the central part of the state between Charlotte and Raleigh. Agriculture is distributed throughout North Carolina. The eastern and central parts of the state produce primarily grains, tobacco, field crops, and livestock. The central and western parts of North Carolina produce primarily dairy and beef cattle, grains, lumber and wood products, orchard crops, and Christmas trees. The North Carolina population increase, both permanent and seasonal, has introduced more traffic on what were once quiet rural roads, as well as motorists unaccustomed to sharing the road with farm vehicles.

Figure 1 shows a five–year trend of reported farm vehicle public road crashes for North Carolina, categorized by farm equipment and farm tractor, averaging 300 crashes per year. The difference between crashes reported in 1995 (358) and in 1999 (266) (Hughes and Rodgman, 2000) represents a 26% drop in the number of farm vehicle public road crashes reported over a five–year period. This decline in reported farm vehicle crashes could be due in part to a change in reporting thresholds from $500 of damages to $1,000 that occurred in 1996 (Hughes, 2000). Future analyses should address this potential bias in the crash reporting data.

Regarding crash severity, NCDMV data (Hughes and Rodgman, 2000) shows that 2 of every 100 reported crashes involving tractors resulted in a fatality, whereas only 1 of every 100 crashes resulted in a fatality when other farm equipment was involved.

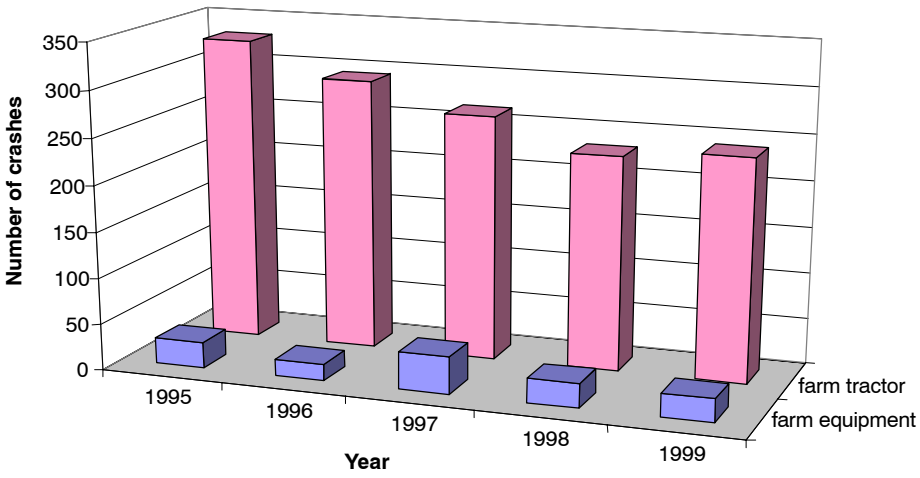

Figure 1. North Carolina farm vehicle public road crashes by tractor and farm equipment, 1995–1999 (from Hughes and Rodgman, 2000).

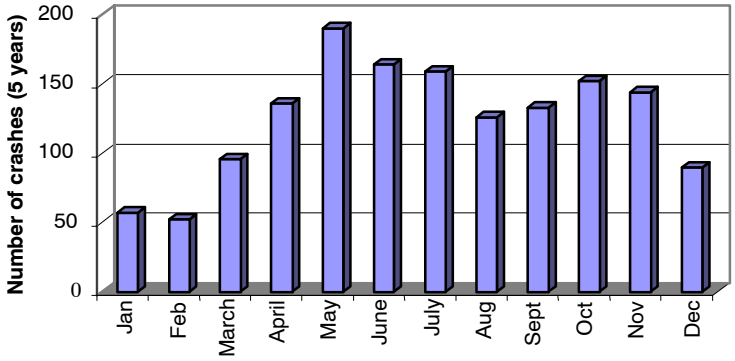

Figure 2. North Carolina farm vehicle public road crashes by month, 1995–1999 (from Hughes and Rodgman, 2000).

Approximately half of all reported farm vehicle public road crashes in North Carolina involved some degree of injury (Hughes and Rodgman, 2000).

NCDMV farm vehicle crash reports show a bi–modal seasonal pattern, with the highest number of crashes occurring in May, June, and July, followed by a second peak in October and November (Hughes and Rodgman, 2000). These months correspond with some of the key planting and harvesting periods for North Carolina farmers, as well as peak tourism and vacation times. Figure 2provides a breakdown by month of farm vehicle crashes for a five–year period (1995–1999) (Hughes and Rodgman, 2000).

The highest number (29%) of North Carolina farm vehicle public road crashes was reported between 3:00 and 6:00 p.m. In addition, large numbers of farm vehicle crashes were reported between 9:00 and 11:59 a.m. (22%) and between 12:00 and 2:59 p.m. (21%) (Hughes and Rodgman, 2000).

Over 75% of all reported North Carolina farm vehicle crashes occurred on either secondary (53.8%) or North Carolina numbered highways (25.6%) (Hughes and Rodgman, 2000). Other roads on which crashes were reported included interstates, U.S. routes, local streets, and private roads (Hughes and Rodgman, 2000). The NCDMV five–year data (1995–1999) indicate that North Carolina farmers were cited in 47% of farm vehicle public road crashes involving tractors (Hughes and Rodgman, 2000). When farm equipment was involved, North Carolina farmers were cited in 53% of the crashes (Hughes and Rodgman, 2000). Operators of non–farm vehicles

Table 1. Reported North Carolina farm vehicle public road crashes by vehicle type and citation, 1995–1999 (from Hughes and Rodgman, 2000).

Farm Vehicles – Tractors		Farm Vehicles – Equipment		Non–Farm Vehicles	
Violation Type	%	Violation Type	%	Violation Type	%
Safe vehicle movement	33.9	Safe vehicle movement	21.1	Fail to reduce speed	23.3
Failure to yield	13.7	Vehicle equipment	21.1	Improper passing	17.0
Vehicle equipment	13.6	Failure to yield	16.7	Safe vehicle movement	4.3
No signal	5.3	Left of center	8.4	Exceed safe speed	3.1
Left of center	3.3	No signal	4.2	Exceeding speed limit	3.1
Other (14 categories)	30.2	Other (9 categories)	28.5	Other (15 categories)	49.2
Total	100.0		100.0		100.0

were cited in 58% of North Carolina farm vehicle public road crashes (Hughes and Rodgman, 2000). Table 1 shows the percentage breakdown of violations issued for farm and non–farm vehicles (Hughes and Rodgman, 2000).

The North Carolina law enforcement violation categories (NCDOT, 1999) listed in table 1 are defined as follows: *safe vehicle movement* – non–specified unsafe driving behavior noted by the reporting officer; *failure to yield* – vehicle did not yield appropriately to other public road traffic; *vehicle equipment* – failure of some component of the vehicle or equipment using public roads contributed to the crash, e.g., faulty coupling or non–functioning signals; *no signal* – vehicle did not have or use appropriate signaling equipment; *left of center* – vehicle crossing the center line of a public road contributed to the public road crash; *failure to reduce speed* – vehicle did not reduce its speed in time to avoid contact; *improper passing* – vehicle did not follow appropriate passing restrictions; *exceed safe speed* – vehicle was traveling at a speed inappropriate for road conditions at the time; *exceeding speed limit* – vehicle was traveling at a speed above the posted limit. Other citation codes are available for use as well; however, they are categorized for the purposes of this analysis as "other."

Failure to reduce speed was the primary cause cited among North Carolina non–farm vehicle operator violations (29.5%), followed by improper passing (17.0%). Farm vehicle operators were cited primarily for the following: vehicle equipment, unsafe movement, failure to yield, being left of the center line, and not signaling. These five categories account for approximately 70% of all North Carolina farm vehicle public road citations in which the farm vehicle operator was cited.

In addition to causes identified through vehicle citations, North Carolina growers, in small group sessions held by NCDOL's Director of Agricultural Safety and Health mentioned difficulty "getting off the road" as a factor contributing to farm vehicle public road crashes (NCDOL, 1999). Lack of shoulders on public roads and the placement of mailboxes and NCDOT signage were mentioned as challenges in getting off the road to provide passing room for non–farm vehicle traffic (NCDOL, 1999). North Carolina growers responding to the mail survey identified "too much traffic" (24%) as their number one public road hazard, followed by speeding (20%) and limited visibility (11%) (NCDOL, 2000).

North Carolina Farm Vehicle Public Road Safety Compared with Key U.S. States

North Carolina is becoming highly urbanized in geographic areas that were historically rural and heavily involved in agriculture. The impact of urbanization on public road traffic patterns affects farm vehicle operators as well as non–farm vehicle operators. To better understand how population change may affect North Carolina farm vehicle public road safety, three agricultural states with varying degrees of urbanization and agricultural production were selected for comparative analysis: Iowa is on the low end of the rural–urbanization continuum. It is one of the largest U.S. agricultural states, yet it is sparsely populated, with agriculture located primarily in rural areas. Michigan is in the middle to upper end of the rural–urbanization continuum in that it has a large agricultural base along with a higher population density than North Carolina. Florida is at the high end of the rural–urbanization continuum in that it has a large agricultural and tourism/retirement base along with a very high population density.

Table 2 compares North Carolina farm vehicle public road crash data with data from Iowa, Michigan, and Florida. Iowa reports the largest average number of farm vehicle public road crashes per year (309) (Schwab, 1997), followed by North

Table 2. Comparison of farm vehicle public road crash rates for selected U.S. states.

States	Average Number of Reported Crashes 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	0.99
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.

Carolina (300) (Hughes and Rodgman, 2000), Michigan (251) (Michigan Farm Bureau, 1999), and Florida (150) (University of Florida, 1991). According to statistics provided by the University of Florida (1991), approximately 30,000 highway crashes involving farm tractors and farm machinery occur each year in the U.S. (these statistics do not include farm trucks, automobiles, or other farm equipment). Annually, approximately one (0.82) farm vehicle crash occurs per day on North Carolina public roads, which is comparable to the daily crash rate in Iowa (0.85) but higher than the daily crash rates in Florida (0.41) and Michigan (0.69).

As mentioned in the Methodology section, the traditional approach to crash analysis requires using vehicle miles traveled (VMT) as the denominator for calculating crash rates. Farm vehicles are typically equipped with an hour usage meter but not with an odometer, and only one study, conducted 30 years ago, was available that measured VMT for farm vehicles on public roads (Doss and Pfister, 1972). In the absence of VMT data for all states, 100,000 inhabitants per year was selected as the denominator for the comparison. Thus, population density is used as the "contextual marker" for farm vehicle public road exposure to a potential crash. When farm vehicle public road crash data are analyzed based on 100,000 inhabitants per year, North Carolina reports an average of 3.90 public road crashes per 100,000 inhabitants, which is higher than rates reported by either Michigan (2.54) or Florida (0.99), but lower than Iowa (10.66).

Cost Impact of Farm Vehicle Public Road Crashes

In an effort to quantify the public health impact of farm vehicle public road crashes, estimates were calculated that incorporate either the impact of exposure to or the financial expense generated by a farm vehicle public road crash. Not included in these public health impact cost estimates are the hidden costs, such as the changes North Carolina farmers make in their public road use in order to minimize their exposure to a farm vehicle public road crash. Future studies and analyses should attempt to assess the changes made by farmers in response to farm vehicle public road crash exposure, as well as identify other hidden costs.

The annual average of 300 reported farm vehicle public road crashes accounts for less than 1% of the total 220,018 public road crashes reported each year in North Carolina. Looking solely at reported crash frequencies, North Carolina farm vehicle public road crashes (300) appear to be a rare event in comparison to the total number of North Carolina public road crashes (220,018) that occur. However, a crashes per vehicle miles traveled (VMT) estimate indicates that North Carolina farmers

experience more farm vehicle public crashes per mile driven than for all vehicles using North Carolina public roads. North Carolina has an all–vehicle rate of 2.47 crashes per million VMT. However, farm vehicle public road crashes per VMT are estimated to be higher, ranging between 3.3 crashes (5 miles/day traveled) and 5.6 crashes (3 miles/day traveled), respectively, per million VMT.

The total North Carolina crashes per million VMT rate was calculated by dividing 220,018 crashes by 89,254 million miles driven on North Carolina public roads (NCDOT, 2002). The denominator for the farm vehicle crashes per million VMT rate was calculated by multiplying an estimated average daily travel distance on North Carolina public roads of three to five miles per day (based on farmer and farm equipment dealer input) times 49,400 North Carolina farmers (USDA, 2000). Thus, farm vehicle public road million VMT rates were estimated to range between 54 and 90 million miles annually. The farm vehicle crashes per million VMT rates cited previously were then calculated by dividing the 300 farm vehicle crashes by 54 million VMT and 90 million VMT, respectively.

These findings suggest that North Carolina farmers are more likely to be involved in a public road crash than the average North Carolina vehicle operator. Further research is needed to better estimate the actual distances farmers are driving farm vehicles on North Carolina public roads.

A cost estimate of the public health impact was calculated using crash costs reported in public road safety and crash prevention studies. A recent study conducted by Ogden (1997), looking at the effects of paved shoulders on crashes on rural public roads in Australia, used AUD $90,000 (approximately U.S. $67,500) as the average cost of a public road crash involving a fatality. The author reported that this figure was based on the whole accident, not just the expenses for one individual. In a study conducted by Sorock et al. (1996) examining the impact of motor vehicle crashes in public road construction work zones, an overturned vehicle was the most costly crash type (median cost = $4,745). This figure was based on total costs of all claims for crashes submitted to Liberty Mutual (Sorock et al., 1996).

Frequently, when farmers try to avoid a crash or get off the road to avoid traffic, a rollover occurs due to uneven terrain (Bonnett, 1999; Farm Safety Association, 2000; NSC, 1999; Schwab, 1997; Templeman, 1997). Therefore, the cost data presented by Sorock et al. (1996) provides a low–end cost estimate for farm vehicle public road crashes. The major difference between farm vehicle crashes and work zone crashes is that, typically in work zones, traffic has been advised to slow down and is merging (Sorock et al., 1996). In the case of farm vehicles, the speed differential plays a critical role (Gerberich et al., 1996), as do signaling and turning issues (Hughes, 2000). North Carolina Department of Transportation data (NCDOT, 2000) indicate an average public road crash expense of $50,000, based on comprehensive crash costs.

Using the three public road crash estimates as a potential minimum ($4,745/crash) (Sorock et al., 1996) and maximum ($67,500/crash for the U.S. and $50,000 for North Carolina) (Ogden, 1997; NCDOT, 2000) range, the annual public health impact of farm vehicle public road crashes in North Carolina and the U.S. can be estimated, as shown in table 3.

Although the data in table 3 are highly speculative, the estimates show that the public health impact of farm vehicle public road crashes, both in North Carolina and the total U.S., may be in the millions of dollars. Public road crash rates are posited to be under–reported due to such factors as reporting thresholds (Aptel et al., 1998; Gerberich et al., 1996). It is possible, therefore, that these figures represent the low end, and present a financially conservative view of the actual public health cost of

Table 3. Estimated annual financial impact of public road crashes involving farm vehicles.

Average Financial Costs	U.S. (average number of annual crashes = 30,000)[a]	North Carolina (average number of annual crashes = 300)[b]
Minimum ($4,745/crash)[c]	$142,350,000	$1,423,500
Maximum ($67,500/crash U.S.; $50,000/crash N.C.)[d]	$2,0250,000,000	$15,000,000

[a] University of Florida, 1991.
[b] Hughes and Rodgman, 2000.
[c] Sorock et al., 1996.
[d] Ogden, 1997.

farm vehicle public road crashes that affect everyone in North Carolina, not just farmers.

Preventive Measures Currently Used to Address the Risk of Farm Vehicle Public Road Crashes

An initial "best practice" analysis of current intervention approaches used to address the public health problem of farm vehicle road crashes was conducted. Preliminary information was collected through telephone conversations with experts in the following geographic areas: Illinois (Aherin, 2000), Iowa (Yapp, 2000), Michigan (Doss, 2000), North Carolina (Luginbuhl, 1999), Pennsylvania (LaBash, 2000), Ontario, Canada (Jeffrey, 2000; Zeronick, 2000), and Tennessee (Prather, 2000). Findings suggest that the main focus of interventions designed to address the risk of farm vehicle public road crashes, incorporate some or all of the following four components:

- Slow–moving vehicle (SMV) signage programs to help farm vehicles be more visible and recognizable as moving at a slower speed than other traffic.
- Several areas, such as Michigan, have passed laws prohibiting use of the SMV sign for other than slow–moving vehicles (Doss, 2000).
- Most areas, including North Carolina (Luginbuhl, 1999; NCDOL, 2000), have incorporated slow–moving vehicle, in particular farm vehicle, information into their driver's education handbook and added corresponding questions to the written driver's test.
- Some areas, like North Carolina, have laws enforcing the type of lighting a farm vehicle must have when traversing public roads, in particular at night, if it is even permitted to be on the road at that time.

A review of ASAE standards shows that farm vehicle public road safety has been addressed through the establishment of guidelines for lighting and marking of agricultural equipment on highways (ANSI/ASAE S279.11 APR01). In addition, two specialized standards are provided: one to address the use of the slow–moving vehicle identification emblem (ANSI/ASAE S276.5 MAY98), and the other to address animal–drawn vehicle lighting and marking (ANSI/ASAE EP576 AUG01).

No programs were identified that specifically incorporate the "share the road" signage/communication message or that had a Department of Transportation (DOT) road signage program in place. A farm vehicle traffic expert in Iowa (Yapp, 2000) reported receiving farmer requests for a "share the road" program (similar to the one developed initially in North Carolina for bicycle public road safety) (FHWA, 2000). In the states contacted for the "best practice" analysis, none reported working with

their respective DOT to identify areas where widening of shoulder widths, roadway signage, or other road conditions, such as visibility, would be addressed.

Findings from the "best practice" analysis indicated a general sense that the issue of farm vehicle public road safety was not considered a priority item on public road safety agendas (Doss, 2000; Jeffrey, 2000; LaBash, 2000; Zeronick, 2000). However, every geographic area contacted identified farm vehicle public road crashes as a significant public health and safety issue that farmers and increasing numbers of community leaders feel is getting worse, not better, and that therefore warrants intervention.

Discussion

The charge of this analysis was to better understand the public health impacts of farm vehicle public road crashes. We asked four questions in examining this issue. Each question and key findings are presented and discussed below.

Research Question 1 – Why might North Carolina growers report increased concern for farm vehicle public road crashes, while NCDMV reported crashes decreased over the same five–year period (1995–1999)?

North Carolina farmer input through Gold Star grower meetings and a mail survey indicated an increased concerned for farm vehicle public road crashes. Initial estimates of crashes per VMT for farm vehicles on public roads indicate that farm vehicles may, indeed, be at a greater risk of experiencing a crash than the average North Carolina driver. And when farm vehicle public road crashes occur, studies indicate that injuries and fatalities are likely to occur. Findings from this analysis suggest that increased concern for farm vehicle public road crashes could come from a combination of factors, such as: increased public road traffic; speeding motorists; farm vehicle and non–farm vehicle interactions during left turns and while passing; and road conditions, such as poor visibility and a lack of shoulders.

According to the NCDOT, the number of farm vehicle public road crashes decreased during the same five–year period (1995–1999) in which North Carolina farmers experienced increased concern about public road crashes. Two key factors that could have played a role in the decreased reporting were identified through this analysis: (1) changes in reporting thresholds and limited definitions and instructions for crash data coding, (2) urbanization and increased traffic on public roads, and consequent changes in farmers' public road driving behavior in response to concern about crashes. In order to accurately measure and track farm vehicle public road crashes and the impact of future interventions, it is important to assess the role these factors play in farm vehicle public road crash reporting.

Research Question 2 – Regarding farm vehicle public road crashes, how does North Carolina compare with other key agricultural states?

The average annual number of farm vehicle public road crashes for the four states compared (North Carolina, Florida, Iowa, and Michigan) ranged from 150 to 309. North Carolina had the second highest number of annual reported crashes (300) as well as crashes per 100,000 population annually (3.90), following Iowa (309/10.66). These findings, along with input from farm vehicle public road experts in Michigan, Florida, and Canada, suggest that concerns regarding farm vehicle public road crashes voiced by North Carolina farmers indeed represent a public health concern

that warrants further analysis and intervention work. The findings also suggest that farm vehicle public road safety is a public health problem not limited to North Carolina or even to the U.S. Future best practice analyses should consider including more states as well as other countries to benefit from new approaches and technologies.

Research Question 3 – What individual and environmental factors play roles in farm vehicle public road crashes?

Analysis findings suggest that North Carolina farm vehicle public road crashes follow a pattern that is: (1) seasonal, with peaks during key planting and harvesting periods; (2) dependent on time of day and corresponding with urban rush hour traffic patterns; (3) affected by road conditions, such as visibility and lack of shoulders; (4) focused on a small number of driving behaviors cited as contributing factors to a crash, which are attributed to farmers and non–farm vehicle operators almost equally; and (5) posited to be affected differently based on a rural versus an urban location (e.g., speeding may prove to be a key contributing factor in rural locations, while increased exposure to a crash may be the most influential factor for farmers in urban locations). Finally, VMT estimates suggest that farm vehicles travel in a limited area and for short distances when using public roads. These characteristics of farm vehicle public road crashes should be included in future analyses, research, and interventions to more fully understand their role in farm vehicle public road crashes.

Research Question 4 – What kinds of prevention measures are currently in place in North Carolina and other agricultural regions faced with this safety issue?

Findings of the best practice analysis indicate that current laws and standards focus primarily on farm vehicle lighting, SMV signage, markings, and farm vehicle public road usage. Although the non–farm vehicle operator is cited as often as farmers in farm vehicle public road crash reports, the only intervention found focusing on the non–farm vehicle operator was recently introduced in North Carolina. The intervention consisted of information added to the North Carolina driver's education handbook and corresponding questions added to the written driver's test. No state was found for the best practice analysis to have a farm vehicle public road safety program incorporating DOT or a comprehensive "share the road" program that included farm vehicle operator concerns in public road traffic planning. Given the importance of agriculture in North Carolina and the increasing competition for North Carolina public roads, the incorporation of farm vehicle public road concerns in traffic planning is an important step in addressing farm vehicle public safety concerns of both farmers and non–farm vehicle operators. Further "best practice" analyses should focus on states that have initiated public road design and signage programs to determine how effective they would be in helping North Carolina address its farm vehicle public road safety concerns.

Limitations and Needs for Future Research

This article is a first step in a program of study and intervention focused on addressing the concerns voiced by North Carolina farmers regarding farm vehicle public road crashes. The limitations in conducting this type of analysis were numerous. Data were often incomplete, biased, old, or non–existent. Terms and

definitions were not well established. And available data allowed only retrospective analysis, limiting our ability to examine what happens when farm vehicles are on public roads. A key denominator used for comparative public road traffic analyses (i.e., VMT) has not been measured except in one study conducted 30 years ago. And the farmer samples in studies available for analysis were not randomly selected, limiting the generalizability of findings to their use in comparative analyses.

In an effort to address these points of weakness, future research should capture a random sample of farmers, in an effort to minimize sampling bias and to allow for more rigorous data analysis. In addition, studies should be conducted prospectively, to provide a more causal perspective of the individual and environmental factors influencing farm vehicle public road crashes. This would include efforts to better understand the relationship between increasing concerns about farm vehicle public road crashes and decreasing levels of crash reporting. Future research should also include an additional "best practice" analysis that evaluates state–level public road safety intervention and traffic planning programs that incorporate a "share the road" component. Cost–benefit analysis data for state–level public road safety programs will be valuable in refining public health costs analyses, as well as in identifying cost effective "best practice" approaches to take in addressing North Carolina farm vehicle public road crashes.

Conclusion

The findings of this analysis using primary and secondary data sources provide an overview of the farm vehicle public road safety challenge in North Carolina. The results suggest that North Carolina is not alone in attempting to address this public health concern. It is hoped that the findings presented here and the recommendations made for future research and intervention will prompt increased multidisciplinary discussion and interaction to increase farm vehicle public road safety. Even with shifts in the economic base in North Carolina and other parts of the U.S. and Canada, agriculture will continue to play a vital role in local communities. Farmers must be able to share public roads with other members of their economic community, without having to experience more than their fair share of concern for a crash.

The nature of farming in North Carolina, as well as in other geographic areas, is changing. Although the number of farms in North Carolina has decreased by more than 66.7% over the last 23 years (1964–1997), the number of harvested acres in North Carolina has increased by 6.2% (USDA, 2000) during that same period. North Carolina farms are becoming larger, and larger farm vehicles are transported on public roads. It is also possible that urban development and economic pressures are placing farmers in a situation in which their fields are not contiguous, thus requiring increased farm vehicle use of North Carolina public roads. In addition, competition for North Carolina public roads is increasing in areas that were once primarily quiet, rural, and sparsely traveled. North Carolina farmers are also allowing more non–family employees, whose first language may not be English, to drive farm vehicles on public roads. Further research and intervention efforts are warranted to help North Carolina farmers, non–farm vehicle operators, and North Carolina transportation experts better understand how all of these factors influence farm vehicle public road crashes in order to reduce their public health impacts.

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