Journal of Agricultural Science; Vol. 10, No. 6; 2018
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Use of Safety Components to Avoid Accidents With Agricultural Tractors in Public Roads

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Received: March 28, 2018 Accepted: April 27, 2018 Online Published: May 15, 2018

doi:10.5539/jas.v10n6p217 URL: https://doi.org/10.5539/jas.v10n6p217

The research is financed by CNPQ.

Abstract

The market of agricultural tractors has an important role in the Brazilian economy, as well as the role the tractor plays in agricultural operations. With the rising level of mechanization, the traffic of tractors on public roads consequently increased, thus raising the propensity of occurring accidents. In transit, tractors present low traveling speed, besides being wider machines in comparison to cars, besides also presenting low visibility to the other drivers who use the roads. The relevance of studies that point the problems related to this type of traffic accident is related to its severity, in order to seek preventive measures. In this context, this study aimed to address the interface of safety components related to lighting and signaling with the avoidance of accidents involving agricultural tractors on public roads. This way, studies show aspects such as: the road speed limit, as well as its type and width; the number of vehicles and agricultural machinery in circulation; safety components; lighting and signaling items, influence and help to draw a characterization of accidents involving farm machinery. Among the types of accidents, collision and overturning are the most common. Even if the number of accidents with tractors is lower in relation to automotive vehicles, the severity of the accidents is greater, with propensity of 5 to 8 times more deaths. Therefore, the correct use of safety components and items of lighting and signaling on tractors, in addition to the compliance with laws and regulations, may contribute to reducing the number of accidents with agricultural machines on public roads.

Keywords: lighting and signaling, highway, mechanization, crashes

1. Introduction

The agricultural expansion and the introduction of mechanized activity boosted the development of the country (Castro, 2004; Sologuren, 2015). In proportion, the market of machines accompanied this process in order to meet the domestic demand, so that currently wheeled tractors account for over 80% of total domestic sales of agricultural and highway machinery in Brazil. Out of the total units sold in 2017 (36.964), 70% occurred in the South and Southeast regions, with a highlight for the state of Sao Paulo, which presented the acquisition of 22% of the units (ANFAVEA, 2017).

In 2015, with the rise of the Brazilian market of agricultural machinery, there was a total of 18 brands of tractors operating in Brazil. Out of these, 39% represent companies associated with ANFAVEA, which publishes monthly data for the manufacturing, sales and exports. Concerning the non-associated brands, there are no official data available on the number of tractors sold or manufactured in the country. According to the directory of tractors (2017), there are 240 tractor models in Brazil, with a) 13% up to 49 hp (36 kW), b) 40% from 50 to 99 hp (36.8 to 92.8 kW), c), 18% 100-149 hp (73.4 to 109.6 kW), d) 16% 150-249 hp (110.3 to 183.1 kW) e) 13% over 250 hp (193.9 kW). Still, it is possible to notice that it has been accentuating the use of tractors with higher power, currently being inexpressive the sales of up to 50 hp (36.8 kW), on the contrary of what used to happen in the 70's.

Given the current economy, Brazil is the fourth largest market for agricultural tractors in the world, behind countries such as India, China and the United States (Junger & Diotto, 2018). In addition, the tractor takes a central role in farming operations, characterized as the main source of power (Rinaldi et al., 2016) for operations that require power, traction and support. It is presented as the most widespread machine in agriculture and is seen as a status symbol for the farmer (Cavallo et al., 2014). In this context, authors also agree that, after the land, the machines represent the largest investment for a farm (Gimenez & Milan, 2007; Queiroga et al., 2014.).

The versatility of agricultural applications of the tractor and the growing use of new technologies on the property, require a renewal of this machinery, because the equipment present incompatibility in the connection with mechanisms present in older machines (Ferreira Filho & Felipe, 2007; Vian et al., 2013). Besides that, the new scenario of scale production demanded tractors with more power and technological innovation in the pursuit of high productivity and reducing production costs (Oliveira, 2000; Ferreira Filho & Felipe, 2007; Melo, 2012; Vian et al., 2013; Silva Junior, 2017). Thus, driven by easy credit, Brazil presented in 2016 a fleet of 944,438 tractors, made up more than half with machines with up to ten years of use, presenting the newest composition over the past 29 years, according to Bellochio et al. (2017).

The fleet renewal and the growth of the overall number of tractors in Brazil, as well as the evolution of exploited crop area, show the importance of the use of this equipment in Brazilian agriculture. In the context of accidents, the ones that occur on public roads take relevance due to the intensification in the traffic of tractors. This paper aims to to address the interface of safety components related to lighting and signaling with the avoidance of accidents involving agricultural tractors on public roads.

2. Traffic Tractors on Public Roads

Although designed for the use in agricultural activities, tractors are also used on the move from one area to another, making use not only of roads inside the property, as well as of public roads (Correa et al., 2005; Machado, Ferreira, & Alonço, 2005; Reis & Machado, 2009; Gkritza et al., 2010; Santos, Monteiro, & Macedo, 2013; Macedo, 2014; Harland, Greenan, & Ramirez, 2014; Macedo et al., 2015b; Montemor, Veloso, & Areosa, 2015; Macedo et al., 2016).

Besides that, they present unique characteristics related to their size, presence of safety and protection items, among others, as shown in Figure 1.

Characteristic	Authors
Low speed of displacement in relation to the other vehicles on the road	Correa et al., 2005; Peek-Wing et al., 2007; Costello, Schulman, & Mitchell, 2009; Reis & Machado, 2009; Gkritza et al., 2010; Pinzke et al., 2012; Burin & Bezerra, 2013; Dimitrovski et al., 2013; Santos Monteiro & Macedo, 2013; Greenan et al., 2016; Tuure, Latti, & Kaila, 2016
Greater dimensions, often wider than a traffic lane, also invading the road shoulder	Costello, Schulman, & Mitchell, 2009; Gkritza et al., 2010; Burin & Bezerra, 2013; Santos Monteiro, & Macedo 2013; Greenan et al., 2016
Nonstandard lighting and/or signaling, deficient or missing	Correa et al., 2005; Reis & Machado, 2009; Gkritza et al., 2010; Burin & Bezerra, 2013; Tuure, Latti, & Kaila, 2016; CEMA, 2017
Often carries passengers on the fenders	Reis & Machado, 2009; Santos, Monteiro, & Macedo, 2013
Usage lifespan, in some cases of more than 20 years, which implies on the absence of safety equipment, such as: a) rollover protective structure; b) seat belt; c) mirrors.	Correa et al., 2005; Reis & Machado, 2009; Gkritza et al., 2010; Pinzke et al., 2012; Montemor, Veloso, & Areosa, 2015; CEMA, 2017

Figure 1. Characteristics of tractors in traffic on public roads

The characteristics of tractors (Figure 1) contribute so that the other road users have difficulties interacting with them in traffic. Considering that they are slow and often large vehicles, they become obstacles for other vehicles, which do not always view it time to reduce speed and avoid the collision. In this sense, the tractor conspicuity is important, with a highlight for the items of lighting and signaling.

In the traffic on public roads, agricultural tractors are characterized as slow vehicles. With a maximum speed of 40 km/h, and under these traffic conditions, they generally maintain speed between 15 and 20 km/h, far below the speed achieved by other vehicles and below the speed limit allowed on the road (Macedo, 2014). In Brazil, in

the absence of regulatory signs, the maximum speed on urban roads ranges from 30 km/h on local roads, to 80 km/h on rapid transit routes. In the case of rural roads, the maximum speed ranges from 60 km/h on roads, 100 km/h in single lane highways and 110 km/h in multiple lane highways (CTB, 2008).

Gkritza et al. (2010) point out that accidents involving older tractors are more likely to cause more severe injuries and fatalities, as in the study by Montemor, Veloso, and Areosa (2015) in Portugal. The compatibility of dimensions of the tractor and the traffic lanes is another aspect to be considered, and in Brazil, the maximum width for machines to go on roads is 2.8 m (CTB, 2008).

3. Accidents With Tractors on Public Roads

The highway system is the main means of transporting cargo and passengers in the country traffic (Pereira & Lessa, 2011). The data released by the National Department of Infrastructure and Transport (DNIT, 2014) show that Brazil has 1.71 million kilometers of roads, being 7% federal roads, 15% state roads and 78% municipal roads. The number of kilometers of roads, increased by only 21% from 1974 to 2014, according to data from the statistical yearbooks of the former Executive Group for Integration of Transport Policy (GEIPOT), between the period of 1977 to 2005 and reports by DNIT (2014).

Concerning the Brazilian fleet of vehicles, data released by ANFAVEA (2017) indicate that the annual number of licensed vehicles is increasing. Thus, it is possible to estimate an increase in the fleet of vehicles, greater than 600% in 40 years. The ratio of the number of kilometers of roads and vehicle fleet show an intensification of vehicles in the Brazilian traffic, with the predominance of automobiles. Agricultural tractors correspond to 1.7% of the total fleet.

In addition to the increased volume and density of vehicles in traffic, high speed limits, type and width of the road lanes are factors associated with the occurrence of accidents with farm machinery on public roads (Greenan et al., 2016). Studies by Costello, Schulman, and Mitchell (2009), Harland et al. (2014), and Greenan et al. (2016) showed that the addition of vehicle density in traffic strongly contributes to the occurrence of accidents, increasing the risk of collisions with farm equipment.

Data from the World Health Organization (2015a) reveal that 1.25 million people die each year in traffic accidents. Low-income countries have fatality rates twice higher than those of high-income countries, with a number of deaths disproportionate to the level of motorization in these countries: 90% of deaths by injuries occur in low and middle-income countries, which hold only 54% of vehicles worldwide (WHO, 2015b). As an example, in the European Union 400 deaths occur annually in accidents with farm machinery on the roads, mostly with tractors with over 13 years of use (CEMA European Agricultural Machinery, 2017).

The increasing use of tractors in the agricultural mechanization process led the characteristics of their security items to evolve as well. On the other hand, the occurrence of accidents remains, for working with tractors is highly susceptible to accidents, according to Fernandes (2014), and Silva (2015). This fact contributes so that to one in three rural work accidents involving agricultural machinery results in the worker's permanent disability (ILO, 2004).

Work accidents are of enormous social and economic importance. Statistical studies have shown the seriousness of this problem, either for their incidence, age of the injured, or their consequences. These accidents are becoming more common, not only in the countryside but also on highways due to the constant traffic of agricultural machinery, whether to change the workplace or to transport goods and supplies (Monteiro, 2010). However, according to Pinzke and Lundqvist (2004), Gkritza et al. (2010), and Haraland et al. (2014), at least one in three cases of accidents with farm machinery on public roads occur in urban areas.

In Brazil, as in other parts of the world, such as Portugal, data from accidents do not exactly express the reality for not being always communicated or for containing misleading information on the record (Alonço, 2004; Montemor et al., 2015). The greater the number of registry details, the better the targeting of appropriate measures of prevention and correction, either in design, protective equipment or training and qualification programs.

In this sense, the publications on accidents with tractors in Brazilian public roads in the last five years appear to be incipient, for almost all of them are developed by a single laboratory and are applied to federal highways, with the possibility of expanding studies to state and local highways. Moreover, it is possible for technical/scientific articles to be developed in more depth and discussion, for greater disclosure of scope in the academic and scientific community through publication in journals, so that they can support prevention and control actions (Bellochio et al., 2018b).

According to Monteiro and Mota (2015), the number of deaths by accidents with agricultural machinery is almost equivalent between those that occur inside the properties and those on Brazilian roads, highlighting rolling over and collision as the most common types of accidents. Mota et al. (2013) observed that certain types of accidents are restricted or occur almost exclusively in certain places. Thus, collision is cited as a type of accident that occurs 95% of the times on traffic routes, as follows: 60% on highways, 21% on streets and 15% on roads.

4. Characterization of Accidents With Tractors on Public Roads

According to the studies of Gkritza et al. (2010), Pinzke et al. (2012), Dimitrovsky (2013), Mota (2013), Lopes et al. (2014), Macedo (2014), Miller et al. (2014a, 2014b), Santos et al. (2014), Macedo et al. (2015a, 2015b, 2016), and Montemor et al. (2015), on the characteristics of accidents with farm machinery on public roads, the main occurence is the collision of other vehicles with the slow vehicle. These data are compared in Figure 2.

				Type of collision						Part of the day			Age		Severity		
Author	Year	Country	Place	% Total	% Rear end	% Lateral	Transversal	% Frontal	% With objects	% Morning	% Afternoon	% Night	Age range	% At age	% Minor injuries No injuries	% Severe Injuries	% Fatal
Pinzke e Lundqvist	**2004**	Swedish	Highways	**83**	30	27	26	-	-	-	-	-	-	-	72	25	3
Gkritza et al.	**2010**	EUA	Iowa	**68,5**	27,8	36,5		4,2	-	9 a	14,2 a	38,8 a	35 a 54	38	89	11	
Pinzke et al.	**2012**	Swedish	Highways	**81**	15,1	35,6	16,6	13,7	-	77		33	25 a 55	50	83,8	13,5	2,8
Dimitrovsky	**2013**	Macedonia	Highways	**40,43 b**	-	-	-	-	-	-	-	-	-	-	73,7	20,5	5,7
Mota	**2013**	Brazil	Brazil	**38 c**	-	-	-	-	-	34,5 c	38,9 c	26,6 c	40 a 59 c	48 c	71 d		29 d
Harland et el.	**2014**	EUA	Great Plains region**	**87,4**	24	29,3	18	2,7	-	30,6	46,6	22,8	-	-	-	-	-
Macedo	**2014**	Brazil	Highways*	**81,6**	33,8	21,7	15,9	3,6	6,6	35,3	39	25,6	25 a 30 35 a 39	30	-	-	-
Macedo et al.	**2015**	Brazil	Rio Grande do Sul*	**88,8**	38,3	17,8	25,2	1,9	5,6	34,6	39,3	26,1	35 a 44	31	-	-	-
Macedo et al.	**2015**	Brazil	Minas Gerais*	**75,7**	28,4	23	15,5	-	8,8	39,9	41,9	18,2	25 a 30 35 a 39	29	-	-	-
Montemor et al.	**2015**	Portugal	Highways	**28**	-	-	-	-	-	-	33	-	45 a 65	36	5	51	44
Macedo et al.	**2016**	Brazil	Goiás*	**78,3**	39,1	17,4	13	4,4	4,4	21,7	37	41,3	35 a 39 50 a 54	35	-	-	-

Figure 2. Characterization of accidents with farm machinery on public roads

Note. "*" Represents Brazilian federal highways; "**" Iowa, Illinois, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin; "a" represents the occurrence percentage at rush-hour times; "b" relative to the number of deaths by collision; "c" relative to accidents inside properties and on highways; "d" relative to collisions only; "e" severe and serious injuries.

In analyzing the data of Figure 2, it is possible to verify that the collisions indices range from 28% to 88.8%. Out of these, the highest percentages are rear-end collisions, ranging from 15.1% to 39.1%, followed by lateral or transversal and frontal. The transversal collisions occur with the impact between vehicles so that they intersect orthogonally or obliquely.

In Brazil, the average of total collisions is similar to the data of Sweden, presented by Pinzke and Lundqvist (2004), and Pinze et al. (2012), and of the grain producing region of the United States, appointed by Harland et al. (2014). Still, it is positioned just above the data submitted by Gkritza et al. (2010) in the American state of Iowa, and is approximately 3 times higher than the values of collisions presented by Montemor et al. (2016) in Portuguese highways.

In relation to the part of the day, in the Brazilian federal roads, the lowest number of occurrences is at night, the afternoon having a slightly higher percentage compared to the morning. This behavior also follows in the states of Rio Grande do Sul and Minas Gerais, corroborating the results of the study by Harald et al. (2014) in the states of Iowa, Illinois, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin in the United States. In the Brazilian state of Goiás, the number of cases is higher at night, followed by the afternoon and the morning shifts.

The age group of 25 to 34 year-olds concentrates the majority of cases in Brazil, with 39% (Macedo, 2014). In Sweden, half the accidents with tractors in traffic routes are with drivers in the age group of 25-55 year-olds. In Portugal, the age group from 45 to 65 concentrates 36% of accidents (Montemor et al., 2015). Finally, in the US state of Iowa, according to Gkritza et al. (2010), 38% of cases are with people aged between 35 and 54 years old. Thus, it is possible to relate the greatest number of cases with more mature operators and drivers.

Regarding the severity of accidents, the Brazilian studies do not present these data. However, the data presented for Sweden, Macedonia, and the state of Iowa show that for each one hundred instances, on average, 80 are with mild or no injury and 20 with severe injuries or fatalities (Figure 2). In Portugal, according to the study by Montemor et al. (2015), the number of severe injuries or fatalities is near the totality, due to the tractor fleet being old and not having safety items such as the rollover protection structure and seatbelt.

It is important to highlight that the number of accidents involving agricultural tractors on public roads is lower than with motor vehicles. However, when it relates to their severity, accidents with tractors have 5-8 times more fatalities (Costello, Schulman, & Mitchell, 2009; ANSR, 2014; Monteiro, 2014; Santos, 2014). In Portugal, in 2014, the number of drivers killed in accidents with tractors on public roads was eight times higher than with cars or trucks (Figure 3).

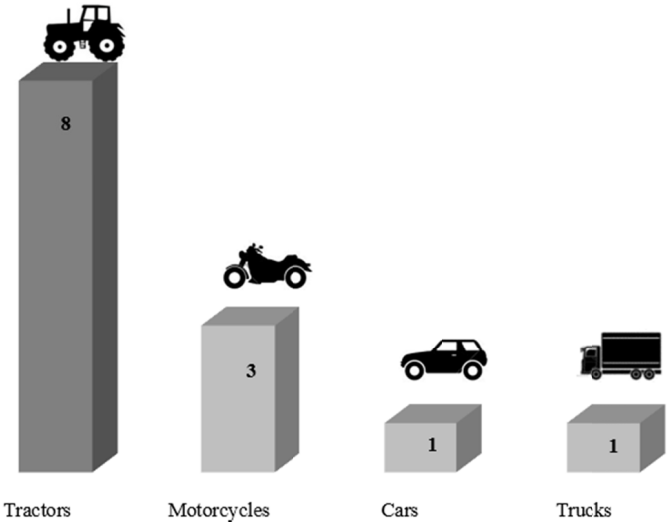

Figure 3. Number of drivers killed per 100 drivers involved in accidents on public roads in Portugal

Source: Adapted from ANSR, 2014.

According to Gkritza et al. (2010), rear-end collisions in agricultural machinery showed greater likelihood of occurrence of severe injuries or fatalities, compared to other types of collisions. The concern with this problem does not affect only the farmers but also other users of public roads. The injuries to the drivers of other vehicles involved in crashes present severity 5 times higher than to the drivers of the agricultural vehicle (Peek-Asa et al., 2007).

Most collisions are attributed to the speed difference between the agricultural machine and other road vehicles (Peek-Asa et al., 2007, Gkritza et al., 2010; Pinzke et al., 2012; Dimitrovsky, 2013; Greenan, 2016; Tuure, Latti, & Kaila, 2016). The accidents on highways with speed limits higher than 70 km/h are highlighted, as the reaction time when viewing a slow vehicle decreases with the increased speed. Besides this, the lack of familiarity of the other drivers with these machines in traffic hinders their interaction, as for the perception of displacement time, as for their dimensions (Luginbuhl, Jones, & Langley, 2003; Pinzke & Lundqvist, 2004; Peek-Asa et al., 2007, Gkritza et al., 2010; Pinzke et al., 2012; Greenan et al., 2016; Tuure, Latti, & Kaila, 2016). These factors are presented as challenges to the drivers to have the discernment and the braking time in the attempt to avoid a rear-end collision with slow vehicles.

In addition to these, according to reports from CEMA European Agricultural Machinery (2017), the five most important factors, responsible for 80% of the accidents in Switzerland are: a) rolling over, b) the behavior of other road users, c) visibility of the agricultural tractor, d) maintenance of agricultural machinery and, e) driver

behavior. Thus, the accident reduction actions were based on these factors, especially with the adaptation of lighting and signaling items for the whole fleet and periodical technical inspection of these items, which aims to a better conspicuity of the agricultural machine, because the defective backlighting contributes significantly to the occurrence of the accident.

Ramirez et al. (2016) inter-related the compliance of lighting and signaling standards for movement of agricultural vehicles on public roads for 9 agricultural states of the American Midwest with the standards of the American Society of Agricultural and Biological Engineers (ASABE) and with accidents of this nature occurred in each state. The results suggest that there is effectiveness of policies that increase the visibility and conspicuity of the agricultural equipment to reduce collisions. It was also analyzed the impact of the components of the lighting and signaling system. The lighting (such as headlights, position lights, direction indicators) is significantly more noticeable, with association of 50% reduction in collisions rates. The signaling (such as the use of retro-reflectors or slow moving vehicle emblems) has a moderate association of 11% reduction.

Gkritza et al. (2010), Greenan et al. (2016), and Murphy (2017) emphasize the importance of meeting US standards for lighting and signaling for agricultural vehicles in order to improve the conspicuity and raise awareness of other road users of the presence of the agricultural vehicle in motion. As measures, they suggest to raise awareness of other drivers for the presence of a slow vehicle on the move in the same direction by implementing improvements in signaling and lighting at the rear of the agricultural machine. Similarly, though applied to trucks, Sullivan and Flannagan (2012) found that the increase in conspicuity by signaling reflectors, provided by the application of the provisions of the specific legislation, provided a reduction in the number of fatal crashes.

This way, possible accident prevention strategies should include better conspicuity and visibility through lighting and signaling of slow vehicles (Luginbuhl, Jones, & Langley, 2003; Correa et al., 2005; Peek-Asa et al., 2007; Reis & Machado, 2009; Gkritza et al., 2010; Fetzer et al, 2012; Pinzke et al., 2012; Greenan et al., 2016; Ramirez et al., 2016; Murphy, 2017). Making the agricultural equipment more visible when in traffic on public roads directs to reducing collisions and the severity of injuries. Alonço (1999), Machado, Ferreira, and Alonço (2005), Reis and Machado (2009); Santos, Monteiro, and Macedo (2013), and Bellochio et al. (2018a) cite the need for the compliance with traffic laws for the transit of tractors on Brazilian roads, as well as the verification and maintenance of the lighting and signaling system.

Thus, according to the World Health Organization (2015b), the laws on road safety, associated with their rigorous and continuous application, improve user behavior and reduce collisions, injuries and deaths in traffic. In this sense, making vehicles safer means to save lives in traffic, however, 80% of the countries around the world, especially those of low and middle income, still do not meet the most basic international standards on vehicle safety.

5. Conclusions

Among the aspects that influence the occurrence of accidents with tractors on the Brazilian roads and highways, it is highlighted the increase in the number of vehicles in circulation and increasing speed limits, as the tractor is a slow vehicle compared to the other vehicles in traffic.

In addition, the type and width of the traffic lane are factors that are correlated with the occurrence of accidents. Within this theme, there is still a gap to be studied, it is the subdivision of accidents in state and municipal Brazilian roads, because their conditions and dimensions may be different and thus interfere with the characterization of accidents.

The analysed studies show that the rear-end collision is the most common type of accident, with the greater likelihood of severe injuries or fatalities occurring in accidents with tractors that have longer usage, due to the lack of safety and protection items. The number of accidents with tractors is lower when compared to cars, however, accidents with tractors present higher severity.

Studies show the effectiveness of the application of regulations as to safety components, lighting and signaling items in reducing collision rates with agricultural machinery on public roads.

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