

AGRICULTURAL MACHINERY ACCIDENTS IN FEDERAL HIGHWAYS IN THE NORTHERN REGION OF BRAZIL

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ABSTRACT: The Brazilian North region is currently going through an agricultural expansion; however farm machinery misuse may increase accidents risks. In the present study was aimed to characterize accidents involving farm tractors on federal highways within the Northern region of Brazil by analyzing their indicators. The study was carried out between 2008 and 2011, in Department of Agricultural Engineering at the Federal University of Ceará, Fortaleza, Ceará state, Brazil in partnership with the Federal Highway Police – PRF. The parameters analysed were location (highway) where the accident happened, accident type and cause, information about victims age, time of day the incident happened and weather conditions. In order to find the minimum amount of samples, operational characteristics curves method was utilized. The collected data was submitted to a nonparametric statistics using frequency analysis and the chi-square test. Most accidents occurred due to lack of attention (62.79% of the total cases) and the main type of the accident was rear collision (32.00%). The afternoon period had more occurrences (38.67%) when compared to the other day periods. The BR-364 federal highway had the highest incidents amount on its extent (34.67%). The accident reports show 75.71% of the total cases happened in good weather conditions.

Keywords: Causes of accidents; Security; Types of accidents.

ACIDENTE COM MÁQUINAS AGRÍCOLAS EM RODOVIAS FEDERAIS DA REGIÃO NORTE DO BRASIL

RESUMO: A região Norte brasileira vem passando por uma expansão agrícola, no entanto o uso demasiado de máquinas agrícolas pode aumentar o risco de acidentes. Assim, objetivou-se caracterizar os acidentes envolvendo tratores nas rodovias federais na região Norte do Brasil, analisando seus indicadores. O estudo foi realizado entre 2008 e 2011, no Departamento de Engenharia Agrícola da Universidade Federal do Ceará, Fortaleza, Ceará, em parceria com a Polícia Rodoviária Federal - PRF. Os parâmetros analisados foram localização (rodovia) onde ocorreu o acidente, tipo de acidente, causa, informações sobre idade das vítimas, horário de ocorrência do evento e condições climáticas. Para encontrar a quantidade mínima de amostras, utilizou-se o método das curvas de características operacionais. Os dados coletados foram submetidos a estatísticas não-paramétricas utilizando-se análise de frequência e o teste do qui-quadrado. A maioria dos acidentes ocorreu por falta de atenção (62,79% do total de casos) e o principal tipo de acidente foi colisão traseira (32,00%). O período da tarde teve

mais ocorrências (38,67%) quando comparado aos outros períodos do dia. A BR-364 teve a maior incidência em sua extensão (34,67%). Os relatórios de acidentes mostram 75,71% do total de casos ocorridos em condições climáticas boas.

Palavras-Chave: Causa de acidente; Segurança; Tipo de acidente.

1 INTRODUCTION

The majority of the Amazon rainforest, one of the most imposing forests in the world, is located in the Northern region of Brazil. However, the North region is currently going through an agricultural expansion. According to the Brazilian Institute of Geography and Statistics, in 2012 the northern region had 2,695,666 ha in area for agricultural purposes having both soybeans and corn as the most planted crops within this area. According to IBGE (2007) the machine fleet in the North region was 26,868 tractors representing approximately 3.3% of the total of the country.

Agricultural tractors are commonly utilized to optimize agricultural production being an indispensable tool in modern agriculture (SANTOS et al., 2014). Tractors are referred as one of the most utilized power sources in rural areas, contributing for rural development and technological advance of food production (MONTEIRO and SANTOS, 2013).

However, farm machinery misuse may increase accidents risk (PATEL, VARMA and KUMAR 2010) currently, tractors have been shown as a major accident factor in rural areas (JONES, DAY and STAINES, 2013). Additionally, the farm machinery fleet has substantially grown throughout the last fifty years. Although, most of the previous mentioned accidents could be avoided if safety regulations were followed.

Due the need to optimize agricultural production and the increasing farm machinery fleet, tractors have been often spotted on public roads, which may increase accident risks involving domestic cars due the tractor lower speed when compared to the other vehicles. Furthermore, operator's both fatigue and inattention as well as design problems referred to

the machines have been found in literature as accident causes (ROZIN et al., 2010).

Monteiro and Santos (2013) point out the loss of control and rollover as the main types of accidents involving tractors in rural areas, but on Minas Gerias public highways collision is the main accident type (MACEDO et al., 2015a), a similar pattern is also observed in India (KUMAR, MOHAN and MAHAJAN, 1998) and Ghana (AIKINS and BARKAH, 2012). However, in Sweden collisions were the third type of accident that most occurred with tractor, accounting for 15.1% of the total cases (PINZKE et al., 2012).

Despite the previous mentioned reports, few studies have been conducted in this field in Brazil, especially involving accidents on public roads. Monereo et al. (2013) states that the recognition of the accidents' cause is the first step to avoid them.

Therefore, the present study aimed to analyze the indicators of accidents involving agricultural machinery on federal highways in the northern region of Brazil, in order to create an accident profile for this region through frequency analysis and chi square independence test.

2 MATERIALS AND METHODS

The experiment was carried out between 2008 and 2011, in the Agricultural Machinery Accident Investigation Laboratory (LIMA), Department of Agricultural Engineering at the Federal University of Ceará, Fortaleza, Ceará state, Brazil.

The incidents' information were provided by the Federal Highway Police (PHP) through Traffic Accident Reports (TAR). The TAR questionnaire is completed by a FHP officer after an accident and, is consequently uploaded on to a FHP databank and which is available to all regional offices within the country. Each report is

filled with the following information, the location (highway) where the accident happened, farm machinery type (dozers, wheel tractor or mixed tractor) and information about the type and cause of the accident. Additionally, dead numbers (fatalities), the time period within the day the case happened and information about the weather condition is available. In the study were analysed 75 reports.

In order to find the minimum amount TAR's for sampling, operational characteristics curves method was utilized (Equation 1), and subsequently from the graph of the operational characteristics curves (HINES et al., 2006) at 5% significance level was possible to find the minimum amount of TAR's. The minimum amount of TAR's required for sampling is 9.

$$d = \frac{|\mu - \mu_0|}{\sigma} \quad (1)$$

Where:

d- amount of samples;

μ - population mean;

μ_0 - sample mean;

σ - standard deviation.

TAR forms for accident involving tractors on federal highways within the Brazilian north region were selected in the period between 2008 and 2011, with a total of 75 occurrences. The accident types verified were frontal, rear, side and cross collision as well as collision with a fixed and mobile objects, rollover, highway run-off, spillage, fire and tipping. The accident causes verified were mechanical failure, lack of attention, alcohol ingestion, road speed incompatibility, prohibited overtaking,

inattention to traffic signs as well as road poor conditions.

The time period within the day the crash occurred was subdivided in 4 classes as follows, morning period (06:00 to 11:59 h), afternoon period (12:00 to 17:59 h), night period (18:00 to 23:59 h) and dawn period (00:00 to 5:59 h). Regarding to the operator's age, the classes have a 5-year-period starting at the age 20 and finishing at the age 60. The last class is above 60 years old. The highways that had episodes reported were BR-364, BR-230, BR-316, BR-010, BR-153, BR-174, BR-319, BR-210, BR-317, BR-222, BR-226, BR-308 and BR-401. Brazilian federal highway names are composed by the BR prefix followed by three numbers.

Results were submitted to a non-parametric statistical analysis through frequency distribution for relative frequency and cumulative relative frequency mainly. To compare each indicator percentage was utilized the chi-square adherence test at 5% significance level (Equation 2).

$$\chi^2 = \sum \left[\frac{(|F_o - F_e| - 0,5)^2}{F_e} \right] \quad (2)$$

Where:

χ^2 - chi-square obtained value;

F_o - observed frequency;

F_e - expected frequency.

3 RESULTS AND DISCUSSION

The chi-square adherence test (Table 1) made it possible to check which classes had significant difference between its indicators.

Table 1. Chi-square adherence test for accident indicators involving agricultural tractor in the Northern region of Brazil

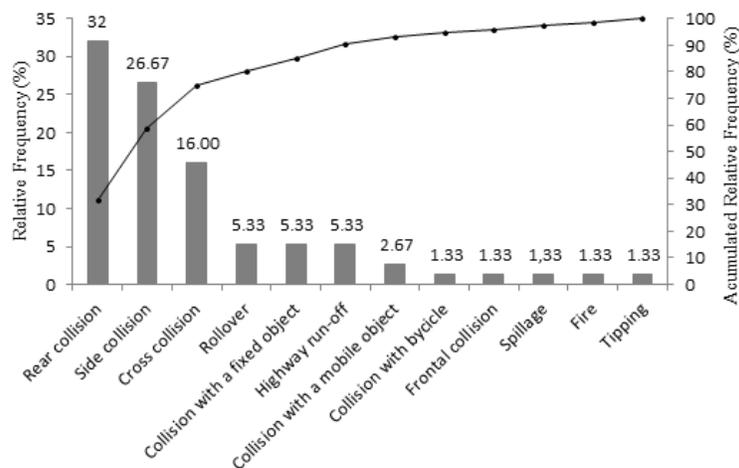
Parameters	χ^2 Cal	χ^2 Tab
Type	113,32*	19,68
Cause	85,44*	12,59
Federal highway on which the accident happened	97,81*	21,03
Operator's group age	11,56 ^{NS}	16,92
Time of day	18,17*	7,81
Climatic conditions	56,60*	5,99

X² tab – tabulated chi-square at 5% significance level; X² cal –calculated chi-square; * (p<0,05); ^{NS} (not significant).

The accident' types, causes, highways, weather conditions and time of day the accident happened had a significant difference at 5% significance level, therefore, at least one indicator of each class is interfering in accident occurrence which is verified because the calculated chi-square is greater than the tabulated chi-square. However, age groups had no significant difference, in other words, no age group is interfering with incident occurrence because the

chi-square tabulated was higher than the calculated. In the present study, there was no correlation between the indicators, there was no adherence test between them, so the influence of each indicator on the other should be analyzed separately.

The most frequent type of accident was a rear collision (32%), followed by a side collision (26.67) and cross collision (16%) (Figure 1).

Figure 1. Frequency of main accident types involving agricultural machinery on federal highways in the Brazilian north region.

Gkritza et al. (2010) found that rear collision had the highest accidents number involving tractors on public roads which corroborates the present study findings. Rear collision has been shown to occur often, fact which could be explained the tractor circulates at low speeds when compared to the other traffic vehicles and even below the minimum speed

allowed on the route. Accidents may happen due either the difficulty for domestic vehicle driver to brake in enough time to avoid the collision or in situations the tractor visibility was compromised due highway topography (contour), for instance.

Side collisions usually occur due to either overtake in prohibited locations or the farm machinery diameter as some machinery are larger

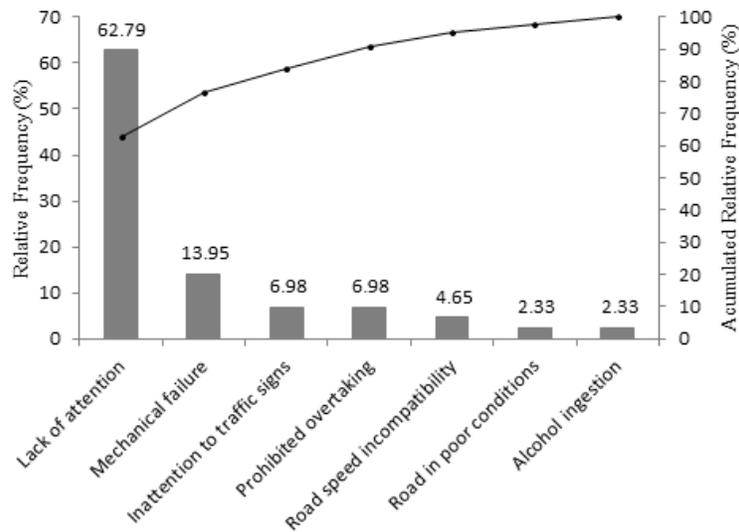
than the limits established by the Brazilian traffic code. Side collision is characterized by a clash side-to-side between the tractor and other vehicle.

The cross collision occurs when a vehicle's front collides with another vehicle on the side, and this type of accident can be credited to traffic signs inattention when drivers or machinery operators drive across a road or enter it when the road is not clear of traffic colliding

other vehicle on the side or in overtaking when the driver ahead also wants to overtake.

The most frequent causes of accidents involving farm machinery on federal highways that cross the Brazilian north region were lack of attention (62.79%), mechanical failure in the vehicle (13.95%) and inattention to traffic signs as well as not keep the recommended safe distance (6.98%) (Figure 2).

Figure 2. Frequency of main accident causes involving farm tractors on federal highways in the Brazilian north region.



The lack of attention is usually linked with extended working shifts which may increase accident risk due tractor mismanagement. Fernandes, Furtado Júnior and Leite (2011) report failures in managing farm machinery are largely responsible for accidents. Regarding to domestic vehicle drivers, a long and tiring journey may reduce both concentration and power of perception which in association with tractor low speed may increase the collision risk. Monteiro and Santos (2013) report that lack of attention accidents are usually associated with fatigue due overwork.

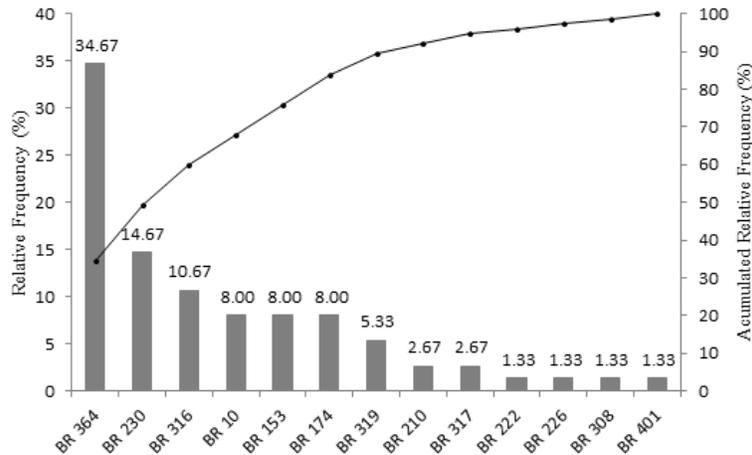
Accidents related to mechanical failures in vehicles can be linked to either improper maintenance or the lack of maintenance which may be due to operators' lack of training. Operators are responsible for tractor

maintenance, therefore, a continued education is needed in order to refresh previously acquired knowledge as well as delivering training courses for operators who have not received this knowledge yet.

Inattention to traffic signs as well as not keep the recommended safe distance indicate that may there is a lack of knowledge about the Brazilian traffic laws or a disrespect of these laws for the drivers related with the accidents such as overtaking in not allowed places and neglect traffic lights.

The Northern highway which had the highest incident numbers on its extent was the BR 364 with 34.64% of the total cases followed by BR 230 and BR 316 with 14.67% and 10.67% respectively (Figure 3).

Figure 3. Brazilian federal highways within the Northern region of Brazil which had farm machinery accidents on its extension and the incidents frequency

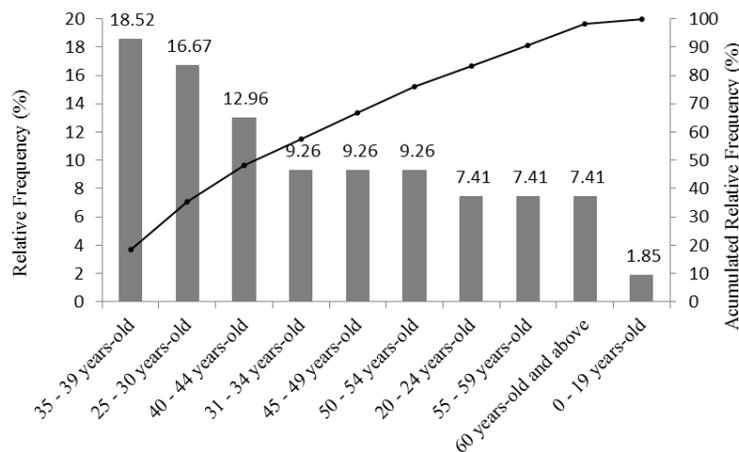


The roads conditions where the accident happened were classified as having good traffic conditions, therefore, accounted as not influencing the accidents. The highway conditions at the time of the accident have high importance in accident's evaluation and may even be pointed by authors as determining factors

in accidents (PEEK-ASA et al., 2007; COSTELLO, SCHULMAN e MITCHEL, 2008).

The operators' age class which had the highest accident percentage was the class 35-39 years-old (18.52%), the second highest was the 25-30 years-old class (16.67%), followed by both 40-44 years (12,96%) (Figure 4).

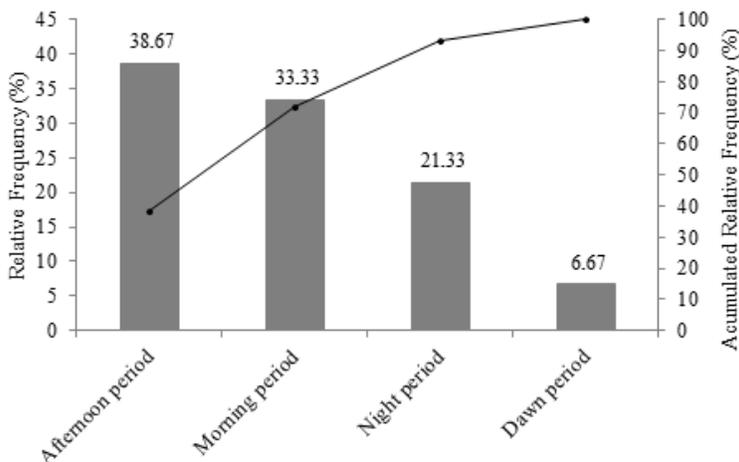
Figure 4. Age group frequency of farm machinery operators involved in accidents on federal highways in in the Brazilian north region.



Although the three already mentioned percentage are larger than the other age groups, there is no statistically difference between age groups, therefore the age of the injured is randomly distributed not having a specific age group responsible for the increase in accidents.

The afternoon period was the time of day which had the highest percentage of incidents (38.67%), followed by morning period (33.33%) night and dawn period with 21.33% and 6.67 % respectively (Figure 5).

Figure 5. Time of day when accidents happened on federal highways in the Brazilian north region.

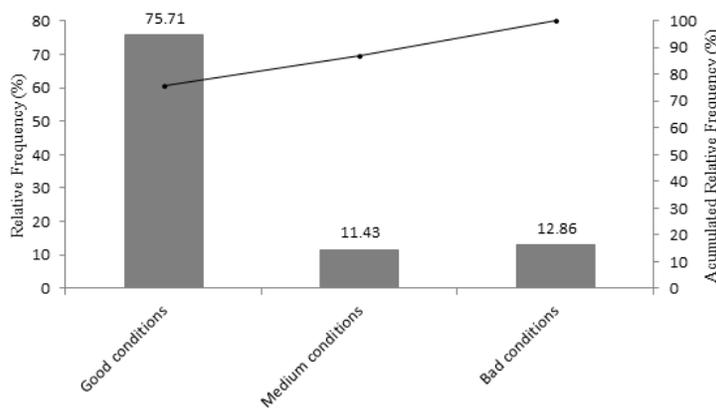


These results corroborate Macedo et al. (2015b) that found the highest accident frequency in the afternoon period, a fact attributed to the greater vehicle flow at the above mentioned period. Despite most accidents occurred during both morning and afternoon periods, the number of accidents at night and dawn periods is worrying (28%) due the fact most agricultural activities are carried out during the day period and only a few activities at night as agrochemicals spraying. Therefore, the high

percentage found is not justified. This may be due to the fact that tractors are being used for other purposes, such as passenger transport, which further aggravates the situation.

Weather conditions when accidents happened were reported to be good (open-sky conditions) (Figure 6). Good climatic conditions correspond to highest percentage of incidents (75.71%), followed by a medium environment (cloudy) (11.43%) and bad circumstances (rain) (12.86%).

Figure 6. Climatic conditions at the time of day when accidents happened on federal highways in in the Brazilian north region.



Most accidents occurred due to lack of attention, mostly rear collisions, in good both highway and weather conditions. Therefore, is possible to argue the occurrence is due to human factors. In order to mitigate the accidents number,

is prudent to recommend the operator have few breaks during the operation process.

4 CONCLUSIONS

The agricultural machinery accidents in the northern region of Brazil usually are collisions occurring due lack of attention. Most incidents happened in the afternoon (38,67%) period with good (75,71%) climatic conditions. The Federal highway the accidents happened most was the BR 364 (34,67%) and there is no statistically specific age that influences the

occurrence of the accidents analysed.. There are few suggestions the author would recommended to mitigate the accidents number. The working period must be decreased in order to reduce fatigue. Training courses for agricultural machinery operators must be held in order to enhance operator's knowledge as well as reducing agricultural tractors traffic on public roads may have a benefit impact on reducing these figures.

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