



## ANALYSIS OF ACCIDENTS INVOLVING AGRICULTURAL TRACTORS IN PUBLIC TRANSPORT IN THE REPUBLIC OF SERBIA FOR THE PERIOD 2014-2024

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**Abstract.** Tractors are among the main causes of numerous accidents in public transport, as well as in agricultural production, forestry, and construction.

Between 2014 and 2024, a total of 150,794 accidents occurred in public transport in the Republic of Serbia, resulting in 214,285 injuries and 5,986 fatalities—an average of 544 deaths per year.

During the analyzed period, tractors were involved in 4,400 road accidents, including 418 fatal ones, which corresponds to an average of 29 deaths per year. Tractor-related accidents also caused 1912 serious and minor injuries, averaging 174 annually.

When examined by month, tractor accidents in public transport most frequently occurred in September, while Saturdays were identified as the most accident-prone day of the week.

In 2014, tractors were involved in 620 road accidents, including 37 fatal ones. By 2024, the number of tractor-related accidents had significantly decreased to 418, with 19 fatalities.

The main causes of accidents involving tractors in public transport in the Republic of Serbia include:

- Non-compliance with the Law on Public Transport,
- Insufficient and discontinuous training of tractor operators,
- Improper technical and operational use of tractors, and
- Alcohol abuse.

Overall, the safety of tractor use in public transport in the Republic of Serbia remains unsatisfactory.

**Keywords:** Republic of Serbia, tractors, accidents, public transport, education

### 1. INTRODUCTION

According to data from the agricultural census of the Republic of Serbia [1], [15], which were published at the end of 2023, the Republic of Serbia has 482,498 tractors of all categories for carrying out work on 4,073,703 hectares of available agricultural land,



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of which 3,275,100 hectares or 80.39% are actively used. Also, according to data from the 2023 agricultural census, 1,150,653 inhabitants of the Republic of Serbia are engaged in agricultural production, which represents 17.4% of the total population.

Of the mentioned total number of tractors (482,498), only 40% are registered, which should mean that they meet the basic technical requirements for participation in public transport. About 350,000 tractors are older than 20 years.

There are also about 2.5 million attached machines and tools in use, of which over 90% are older than 10 years.

From the aforementioned data, it is easy to conclude that the tractor as the basic driving unit in agriculture, either in a unit with attached machines or implements, or as an independent motor vehicle, has a very high-risk factor of causing accidents and thus frequent forms of injury to participants when used in public transport in Serbia.

According to the literature [6], [9], [10], [11] and the data of the Traffic Safety Agency of the Republic of Serbia [2], tractor drivers, today, on different categories of roads in the public traffic of the Republic of Serbia, participate with a high share in causing traffic accidents with different and dangerous consequences.

Tractors have a significant application in agricultural and other works (construction and forestry works) and transport, when moving on different types of surfaces and categories of public roads. In such numerous and different circumstances, tractors are potentially dangerous traction machines, especially if they are not used according to certain rules of safety, prevention, protection and legal regulations.

Data from the literature show [2] that accidents and injuries with tractors most often occur in the spring, when the volume of work in agriculture is increased. Injuries are very diverse, severe and affect all parts of the operator's body, with the appearance of a high degree of disability [6], [9], with mostly large material damages, because the machines are very expensive. Unfortunately, very often there are tragic consequences for drivers and other road users.

The tendency of the annual increase of these machines is from 5,000 to 20,000 pieces due to the increased volume of agricultural works. In addition to this number of tractors, the Republic of Serbia has over 400,000 other types of working machines and more than 30,000 combines [1]. So, the approximate total number of mobile agricultural machines with their own engine and the possibility of participating in public transport in the Republic of Serbia, today exceeds the number of 1,000,000 pieces.

With such a large number of moving machines, there is a high risk of an annual increase in the occurrence of accidents in public transport or in the processes of agricultural production.

At the same time, research [8], [10] should also be noted, which show that the financial effect of the events is of particular importance, since modern tractors as traction-drive and transport units are also designed for movement on public roads, and can reach purchase prices of up to 150,000 EUR or even more (tracked tractors, etc.). The prices of other self-propelled agricultural machines (harvesters) can reach over 200,000 EUR.

Accidents often result in considerable damage to agricultural machinery, which is when additional problems arise for the relevant institutions.



Serbia is not the only country that has serious problems with accidents related to agricultural machinery, primarily tractors. In the world, many researchers [3], [8], [12], [13] consider the tractor as one of the main causes of accidents. Regardless of the development of certain countries in the world in economic, social, technical or any other sense, the obligatory companion of intensive agricultural production and the use of modern agricultural mechanization are accidents that occur as a result of the error of the operator or the state of the machine itself. One example [14], is the agricultural production of the United States of America. there are 2.2 million workers in American agriculture, which represents 1.4% of the total number of workers in the economy. On average, around 500 accidents with tragic consequences and 120,000 accidents with serious bodily injuries occur in agricultural production. This shows that accidents in agriculture in terms of the number of victims are higher than in other economic branches that are also considered risky (construction, transport), and only in mining is the number of accidents with tragic consequences higher. That is why agriculture in America is an industry with a high risk of workplace injuries. A large number of accidents are precisely those involving agricultural machinery, primarily tractors, and then other mobile agricultural machines. Research conducted on the Australian continent [7], [13], shows that tractor accidents account for as much as 72% of the total number of accidents in agriculture. Of the total number of accidents with tractors, 61% are accidents with tractor overturning. The statistical analysis of the collected data in the three-year period of the research shows that there is no statistically significant decrease in accidents with tractor overturning, while other types of accidents with tractors show a significant increase. Analysis shows that tractors are the most common cause of agricultural fatalities in Australia. A report from Western Australia [7], for the period 2014 to 2024 found that tractors were the most common cause of agricultural fatalities, with 12 deaths per year.

In contemporary global practice, considerable attention is devoted to safety [3], [12], [13], security, and the enhancement of the technical culture of farmers, particularly operators of all working machines that may also participate in public traffic.

This is primarily achieved through educational activities and the organization of various training programs.

Ergonomics also contributes significantly to improving the level of safety in this field. The integrated signaling devices installed in tractor cabins [4], [6] through both audio and visual signals serve to inform and warn the operator of potential hazards that may arise during the work process, thereby preventing possible injuries and other accidents with potentially tragic consequences.

## 2. MATERIAL AND METHODS

Accidents Involving Tractors in public traffic in the Republic of Serbia during the period 2014–2024 were analyzed within the scope of transport activities of tractors and attached machinery during their movement/operation in public traffic on various categories of roads in the Republic of Serbia.

Data on the number of accidents [2], [15] involving tractors in public traffic were

collected from the Traffic Police Directorate and the Road Traffic Safety Agency of the Republic of Serbia.

The data presented in this paper are shown in tabular and graphical form and analyzed by year and by the consequences of the accidents for the period from 2014 to 2024.

### 3. RESEARCH RESULTS

Tractors have significant application in agricultural operations and transport when operating on agricultural land of various characteristics (soil with different topographical features, uncategorized roads, etc.) as well as on various categories of public roads. In these situations, they represent a potentially hazardous machine, especially if they are not used in accordance with established safety, preventive, and protective regulations.

In the literature [7], [9], [14], the human operator and the tractor are most frequently cited as constant causes of numerous accidents in agriculture, forestry, and construction, where the most common causes include: improper handling (driving tractors with inadequate technique or at inappropriate speeds in traffic, on slopes, or on lateral inclines, leading to rollovers), and maintenance-related causes (various repairs or interventions on individual components, tire replacement, refueling, adding coolant, etc.).

According to literature sources [6], [9], in the period from 1999 to 2009, in public traffic in the Republic of Serbia, an average of 469 persons were injured annually in tractor-related accidents, while an average of 62 tractor operators were fatally injured each year.

It was also determined that 144 tractor drivers were severely injured (resulting in permanent disability) annually. It should be particularly emphasized that the material damage resulting from these accidents is enormous.



**Figure 1.** Accidents Involving Tractors and Fatal Consequences.

The most common causes of accidents in agricultural production and public traffic [6], [9], involving tractors and other self-propelled agricultural machines are:



- carelessness of the machine operator,
- insufficient level of training for operation,
- non-compliance with traffic regulations,
- lack of knowledge of safety measures, and
- the use of technically outdated or defective machines.

**Table 1.** Consequences of traffic accidents involving tractor drivers in the period from 2014 to 2024.

Year	Number of accidents - public transport	Number of injured persons - public transport	Number of tragically injured persons - public transport	Number of injured persons - tractors	Number of tragically injured persons - tractors
2014	13068	18025	536	162	37
2015	13656	19350	599	187	33
2016	14409	20655	607	195	40
2017	14809	21631	579	177	29
2018	14236	20845	548	195	27
2019	14244	20418	534	164	28
2020	12311	17259	492	189	26
2021	13786	19965	521	156	24
2022	13269	19119	553	194	33
2023	13463	19059	503	143	26
2024	13543	17959	514	150	19
Ukupno	150794	214285	5986	1912	322
Prosek	12477	17848	544	174	29
%		100*	100**	0,97%*	5,4%**

\* in relation to the total number of injured

\*\* in relation to the total number of casualties

In the territory of the Republic of Serbia, according to research, during the period from 2014 to 2024, tractor drivers were frequently involved in direct traffic accidents in public traffic (injured persons). The data on the number of persons injured in traffic accidents (Table 1), which were caused by tractor drivers or in which they were direct participants, for the period 2014–2024, indicate a serious aspect of accidents caused by the interaction between humans and tractors.

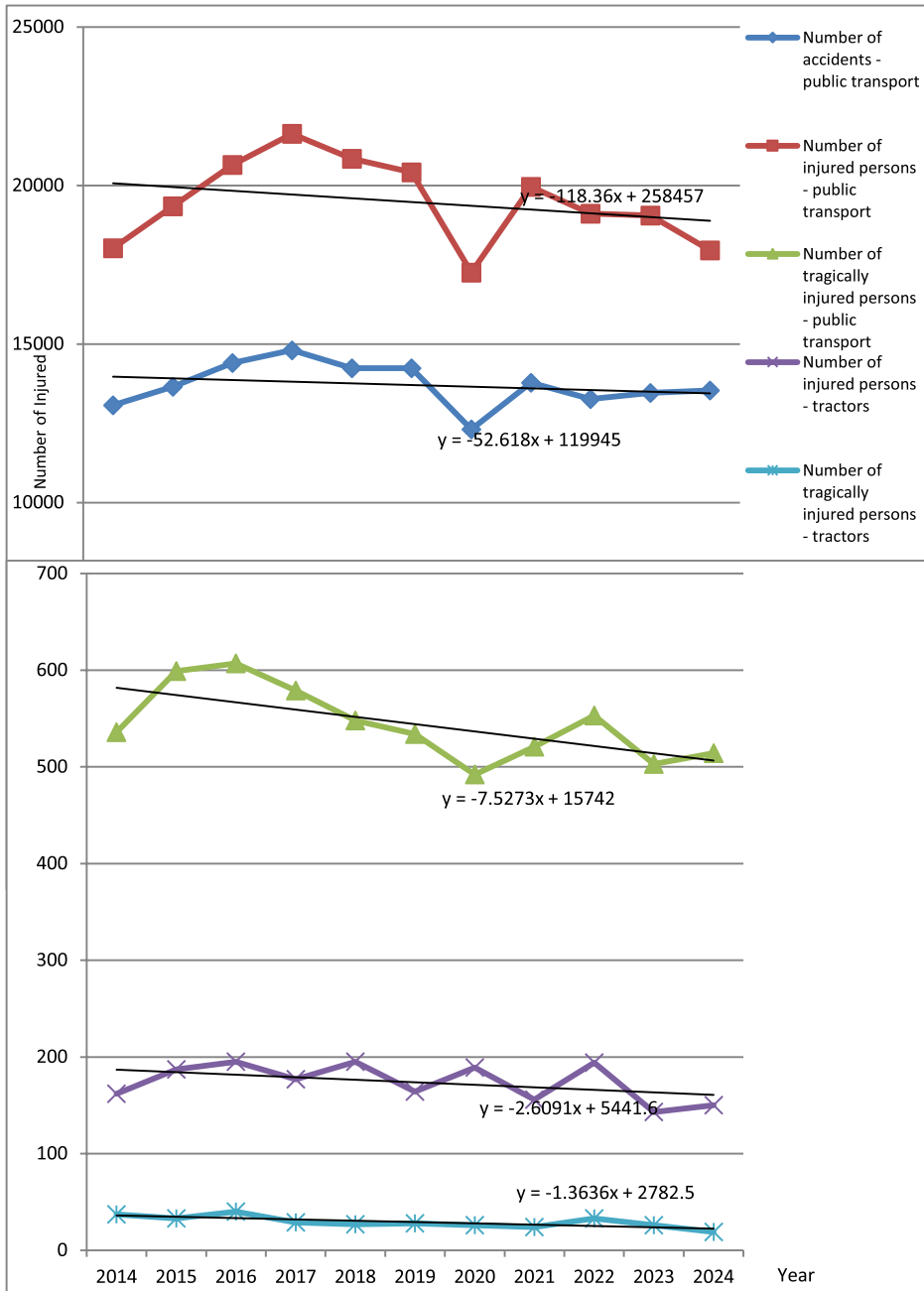


Figure 2. Graphical representation and trend of the consequences of traffic accidents involving tractor drivers for the period 2014–2024.



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By analyzing the presented data (Table 1, Fig. 2), concerning results are observed regarding the number of casualties.

In public traffic in the Republic of Serbia in the research period from 2014 to 2024, out of the recorded 150,794 traffic accidents, a total of 5,986 persons were fatally injured and 214,285 persons were slightly or severely injured. In accidents caused by or involving tractor operators and other agricultural machinery, a total of 1,912 persons were slightly or severely injured, which represents 0.97% of the total number of the injured, while 322 persons were fatally injured, or 5.4% of the total number of fatal casualties.

In particular, the analysis of accidents involving tractors shows positive changes in the direction of reducing the number of such incidents. The number of injured persons decreased from 162 to 150 during the analyzed period, with an average decline of about one person per year. The number of fatalities in these accidents shows the most significant reduction across the dataset — from 37 deaths in 2014 to 19 deaths in 2024.

The collected data indicate that for all categories of consequences, the trend is declining. Although the data show improvement from year to year, the number of fatal casualties remains concerning, with an average of 29 deaths per year during the study period. Based on the presented data, it can be concluded that the number of casualties in accidents involving tractors has slightly decreased in the period from 2014 to 2024.

In general, the data indicate that the total number of traffic accidents is not decreasing, but the number of the most severe outcomes is decreasing. The reason for this reduction is not solely attributable to human factors, but is largely a consequence of improvements in active and passive vehicle safety, better medical care, increased supervision, and preventive campaigns. The particularly noticeable decline in the number of fatalities in tractor-related accidents may indicate strengthened regulation, mandatory technical inspections, and an increased awareness of safety in rural agricultural communities.

Analysis of the collected data also shows that, when observing days of the week, the highest number of accidents occurs on Saturdays. Regarding months of the year, April is the most critical, which corresponds to the start of the agricultural work season.

Despite all of the above, work with tractors and other agricultural machinery still results in serious and tragic consequences, most often because operators do not perform their tasks in accordance with the existing regulations and safety rules, which are not consistently followed.

Review and analysis of literature [6], [9], [10], [11], as well as research results in the Republic of Serbia, indicate that accidents involving tractors and other mobile agricultural machines continue to occur, despite numerous preventive measures and legal regulations.



**Figure 3.** Faulty and improper tractor units in public traffic in the Republic of Serbia.

This is primarily the result of carelessness, unskilled handling, machinery malfunction (Figure 3), insufficient education and lack of discipline (e.g., factors such as the unauthorized consumption of alcohol during work and transport activities), and the psycho-physical fatigue of tractor and agricultural machinery operators.

The authors of this study believe that accidents also occur due to the lack of continuous professional training and accompanying courses for the proper use and maintenance of tractors and machinery. Such training must be organized and implemented through a continuous, coordinated, and serious effort by all relevant stakeholders, primarily societal institutions (Ministry of Agriculture, Ministry of Infrastructure and Transport, Ministry of Internal Affairs, educational institutions, associations of agricultural producers, and other relevant organizations and individuals).

#### 4. CONCLUSION

Analyses show that traffic accidents involving tractors and other agricultural machinery in public traffic in the Republic of Serbia during the period 2014–2024 exhibit the following main characteristics:

- The average annual number of fatalities in accidents is 544.
- The average number of tractor drivers or participants who died is 29.
- The average number of participants sustaining minor or serious injuries in accidents involving tractors is 174.
- Collected data indicate a downward trend across all categories of consequences. Although the situation shows gradual improvement year by year, the number of fatalities an average of 29 per year during the study period remains concerning.

Accidents involving tractors and agricultural machinery are currently a common occurrence in Serbia, mainly due to insufficient ongoing training and specialized cours-



es for the proper use and maintenance of these machines. There are also significant gaps in knowledge and compliance with basic traffic regulations among tractor operators, as well as irresponsibility and lack of discipline during the use of tractors and other mobile agricultural machinery.

Future research and preventive actions should focus on mandatory operator training and raising technical awareness among operators, alongside enhancing tractor safety through legislative measures requiring the installation of cabins or protective frames and seat belts on all tractors used in Serbian agriculture.

The imperative for the coming period is to reduce the number of accidents involving tractors and agricultural machinery to the lowest possible level. This primarily requires ensuring that agricultural production processes are carried out in full compliance with all prescribed safety measures and labor regulations, and especially the Road Traffic Safety Law [5], when these machines are involved in transportation on public roads.

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