

## INFLUENCE OF ROAD USER BEHAVIOR ON OCCURRENCE OF ACCIDENT: AGRICULTURAL VEHICLES AND MOTORCYCLISTS

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**Abstract.** The heightened presence of agricultural vehicles on roads is driven by the seasonal nature of agricultural operations. These vehicles are typically wider, heavier and slower than other road vehicles, significantly impacting the traffic flow and posing a safety concern. While accidents involving agricultural vehicles are less frequent compared to those involving other road vehicles, their severity is often far greater. In the event of a collision between an agricultural vehicle and one of the most vulnerable road users, the consequences can be particularly severe. If they collide with each other, there is a much higher probability of serious injuries (given their nature and extent), very often with fatal consequences. The most common causes of these traffic collisions include the risky behaviour of road users, disregard for road traffic rules, mental and physical fatigue, vehicle breakdowns, etc. Critical sections where various traffic collisions occur the most are intersections, exits from a side road to the main road or vice versa, wrong turning from the main road to a side road, confusing turns. The paper deals with the analysis of a specific traffic accident involving an agricultural vehicle with a trailer (Zetor Forterra tractor) and motorcycles. This traffic accident was located in the outskirts of the village, on a straight section of the road, on a slight incline, where the maximum speed of 90 kilometers per hour was allowed. The emergence and course of the accident scene is investigated with regard to the specificities of the movement of road traffic participants on roads. As part of the analysis, the speed of the vehicles before the collision, the impact speed with regard to the drivers' vision, the driving technique of the drivers was calculated and evaluated, and the technical cause of the accident event was established. At the end, the possibilities of averting an accident on the part of individual road traffic participants are described.

**Keywords:** analysis, safety, accident event, agricultural vehicle, motorcyclist, risk.

### Introduction

Various traffic collisions of agricultural vehicles with other road vehicles represent a wide range of risks in the field of road user safety, where a number of risk factors related mainly to the components of the road system influence their occurrence. Some traffic collisions are less serious, while others can cause a serious traffic accident with fatal consequences. In a collision between the most vulnerable road users (pedestrians, cyclists, motorcyclists) and an agricultural vehicle, the risk of various serious injuries is clearly higher to the vulnerable than the risk of injuries to the participants in the agricultural vehicle. For example, motorcyclists are not sufficiently protected, especially when falling on the road, sliding on the road or after hitting a fixed obstacle, and are at risk of very serious, even fatal, injuries [1-3],

In traffic accidents involving motorcyclists, the probability of serious, even fatal injuries is approximately 30 times higher than in accidents involving other road vehicles. The consequences of accident events are up to 80% of minor, severe and fatal injuries. Among the most common injuries of motorcyclists are serious head injuries, complicated fractures of the upper, lower limbs and pelvis, spinal cord injuries, internal bleeding, abrasions of various nature depending on the speed of the motorcycle, road surface and protective clothing [4].

The mentioned contribution deals with the analysis of a traffic accident involving an agricultural vehicle (Zetor tractor with a trailer) and motorcyclists riding motorcycles (Suzuki and Yamaha brands). This traffic accident occurred on a Class I road, in the outskirts of the village, in the left lane, when five motorcyclists overtook a convoy of vehicles and a tractor with a trailer turned off the road (onto a forest road). Pursuant to the relevant provisions of the Act NR SR No. 8/2009 Coll. on road traffic, as amended, a driver turning left has the obligation not to endanger the drivers driving behind him and must correctly assess the traffic situation before starting the turn [5]. By his actions, the tractor driver endangered the motorcyclists when turning left and did not pay attention to the motorcyclists when passing a convoy of vehicles, which was a negative element in the occurrence of the traffic accident.

### **Safety of road users (drivers of agricultural vehicles and motorcyclists)**

The safety of road users is a very current and important issue due to the increase in the traffic intensity and the development of other alternative modes of transport. Motorcycles are the main mode of transportation in several developing countries because they are cheaper, more accessible and have greater mobility on crowded roads. An increased number of motorcyclists is recorded especially during the summer months, in spring and autumn, when motorcyclists are a risk factor for the occurrence of various accidents due to their behavior [2; 5]. Riding a motorcycle has completely different parameters than driving a road vehicle. Motorcycles and road vehicles are equipped with different elements of active and passive safety, the main task of which is to prevent and minimize injuries to road users [6].

The probability of the occurrence of various traffic conflicts in congested road traffic mainly represents the difference in the movement of a road vehicle and a motorcycle in the driving lane, as well as outside the driving lane. Motorcyclists very often change the speed and direction of travel, drive in the same lane next to other road vehicles, may swerve or follow the leading vehicle diagonally [3]. Keeping a safe distance also applies between a road vehicle and a motorcycle. Although a motorcycle is a fast vehicle, it has a limited braking effect, as the contact area of its tires with the road is small. Due to the dimensions, the motorcycle can remain in the so-called blind spot of the vehicle, which can be the cause of a collision situation [7]. The most frequent causes of motorcyclist traffic collisions include errors due to inattention, overestimating the abilities, fast driving, dangerous maneuvers, and recklessness towards other road users. Important factors related to the accident rate can also be various technical problems of motorcycles, the condition of the road or any surprising fact, such as an unpredictable turn, a sudden obstacle, an unclear section, which has a significant impact on the driver's ability to anticipate and adapt the ride to the road traffic [8].

Agricultural vehicles are commonly found on roads, especially during seasonal agricultural activities, but due to their greater weight, height, width, length and slower speed compared to other road vehicles, they bring an increased level of safety risk [9]. The negative factors are mainly the insufficient visibility from the driver's seat, the minimal level of risk perception, poor visibility at night, the dimensions and weight of the vehicle and the large kinetic energy of the vehicle upon impact (transmitted to other road users), as well as the movement of agricultural and other off road vehicles on the same (often main) roads (especially during the collection period) [10]. Drivers operating agricultural vehicles and their attachments are exposed to many dangerous influences, such as the effects of extreme temperatures, excessive noise, vibrations, emissions. Physiological fatigue of tractor operators is one of the most important sources of reduced safety, as these drivers often perform full-day (10 or more hours) work. Longer working hours in conjunction with the mentioned negative effects lead to rapid fatigue of drivers and are often associated with the risk of various traffic collisions [11].

According to the available studies, most of the traffic accidents were caused by agricultural vehicle drivers, but some accidents were caused by other factors such as poor road conditions, outdated vehicle equipment, vegetation blocking visibility, wild animals and livestock, etc. Most studies also agree that there is no reliable database of traffic accidents with agricultural vehicles, which often leads to an underestimation of the importance of prevention, education, creation and modification of legal standards [12].

### **Traffic accident analysis – tractor with trailer and motorcyclists**

The traffic accident between two motorcyclists and an agricultural vehicle (a tractor with a Zetor Forterra trailer) occurred in the afternoon on a Class I road, in the outskirts of the village. The tractor driver was driving the vehicle (tractor + trailer) at a speed of approx. 30 km·h<sup>-1</sup>. Behind the driver was a convoy of passenger vehicles (Peugeot and behind him KIA Ceed), which were moving at a speed of about 40 km·h<sup>-1</sup>. This convoy was overtaken by five motorcyclists (X1, X2, X3, X4, X5) at a distance of about 10 m from each other, in the left lane, who were moving at a speed of up to 90 km·h<sup>-1</sup>. Motorcyclists overtook on a straight, clear and relatively long section, on a slight incline, without a traffic sign prohibiting overtaking. The first motorcyclists (X1, X2) overtook the entire column of vehicles without any problems. At the moment when the motorcyclist (X3) on the Suzuki motorcycle was near the rear of the tractor trailer, the driver of the tractor slowed down and began to smoothly turn left onto the forest road, passing into the opposite direction with the front left wheel. The motorcyclist tried to avoid a traffic collision up to the side of the road, but the tractor driver caught the rear part of

his motorcycle (rear wheel) with a blade placed in the front part of the tractor. As a result, the motorcyclist went off his ride (left), hit the guardrail and was thrown onto the road (right), where he landed on his right side and slid down the road, all the way to the right shoulder. The next motorcyclist in line (X4) began to brake intensively after recognizing the collision situation, but nevertheless hit the rear left wheel of the tractor. Subsequently, the motorcycle slipped next to the tractor and fell on the road. The motorcyclist hit the tractor with the right part of his body, and after being thrown onto the road, he slid on it with the left part of his body for several meters. The fifth motorcyclist (X5) managed to stop safely before the collision situation [13].

From a forensic medical point of view, the motorcyclist (X3) was seriously injured, and the motorcyclist (X4) was slightly injured. The X3 motorcyclist suffered an open fracture of the foreleg of the left leg, a fracture of the apple, an open fracture of the little finger of the right hand. The X4 motorcyclist suffered a contusion of the right knee, a tear of the internal collateral ligament, a sprain of the right wrist, a contusion of the left chest [13]. Pursuant to the provisions of the Act NR SR No. 8/2009 Coll. on road traffic (§19, paragraph 1 and §137, paragraph 1) as amended, it is possible to state that the traffic accident was caused by the driver of the tractor, who by his actions endangered motorcyclists when turning left and did not take them into account when going around, which violated the provisions of the aforementioned law [5].

### Place of the crash

At the place of the traffic accident, there are two two-way lanes 3 m wide and there is a guide line with a shoulder on both sides of the road. The lanes are separated by a dashed white line in the middle of the road. On the right there are guardrails, on the left the guardrails start beyond the accident site. On the left side of the road, at a distance of 51.3 m from VBM (starting point of the measurement) is the beginning of the exit of the forest road to the Class I road. The road is surrounded by coniferous forest on both sides. At the time of the traffic accident, the road was in proper technical condition (without defects), visibility was not reduced due to the weather conditions, and viewing conditions were good. The longitudinal and transverse position of the collision between the tractor and the motorcyclist (X3) and the motorcyclist (X4) is shown in Figure 1.

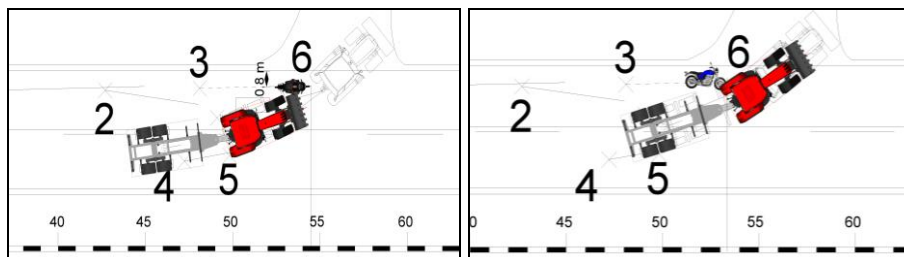


Fig. 1. Location of the collision between the tractor and the Suzuki motorcycle (left) and the collision between the tractor and the Yamaha motorcycle (right) [14]

The longitudinal position of the collision between the tractor and the Suzuki motorcycle (X3) is given by the position of the front wheel of the motorcycle at a distance of approx. 54.5 m from VBM. The transverse position of the collision between the tractor and the Suzuki motorcycle is given by the transverse position of the motorcycle from the left edge of the road approximately 0.8 m. The longitudinal and transverse position of the tractor and motorcyclist (X4) at the point of collision is determined by their relative position at the moment of the collision. The longitudinal position of the collision between the tractor and the Yamaha motorcycle is also given by the position of the front wheel of the motorcycle at a distance of approx. 53.5 m from VBM.

### Speed and trajectory of movement of motorcycles and the tractor with a trailer

Considering the above input data, the PC Crash program calculated the mutual movement of the tractor with a trailer and the Suzuki and Yamaha motorcycles during the accident event. Traces of the movement of the Suzuki motorcycle were left at the scene of the traffic accident, on the basis of which it is possible to evaluate the course of the speed and trajectory of the movement of the motorcycle in the time period after the collision (or the close encounter with the tractor). From the moment of contact

between the tractor and the trailer and the motorcyclist (X3) on the Suzuki motorcycle, it was considered that the motorcyclist began to lose directional stability and did not brake until contact with the barriers. The motorcycle was slowed down due to engine resistance with a deceleration value of approx.  $1.5 \text{ m}\cdot\text{s}^{-2}$ . The calculated value of the speed of the motorcycle at the moment of contact with the tractor (or of close contact with the tractor) was approximately  $85 \text{ km}\cdot\text{h}^{-1}$ .

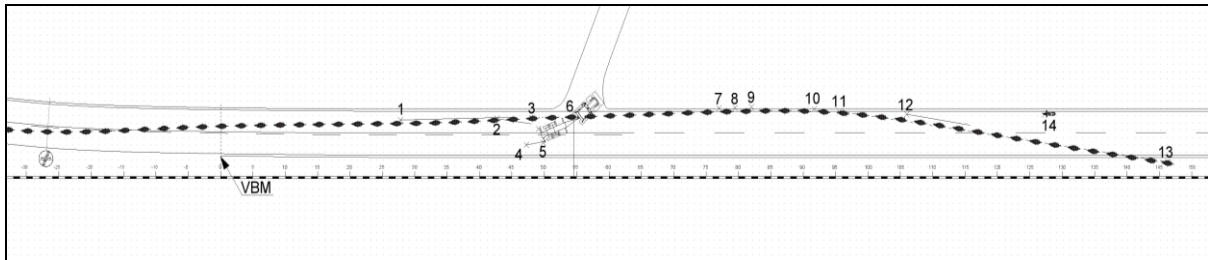


Fig. 2. Trajectory of movement of the Suzuki motorcycle during the accident [14]

For the movement of the Yamaha motorcycle, it was considered that the motorcyclist (X4) was ahead of the line of vehicles, accelerating smoothly, until the moment of his reaction to the turning of the tractor (left). After recognizing that the tractor driver was turning (left), the motorcyclist reacted by braking intensively, during which brake marks were left. The calculation of the movement of the motorcycle during the accident was carried out in such a way that it was technically logical with regard to the motorcyclist's reaction to the tractor turning, to the brake and friction marks left, as well as to the evaluated location of the collision between the motorcycle and the tractor.

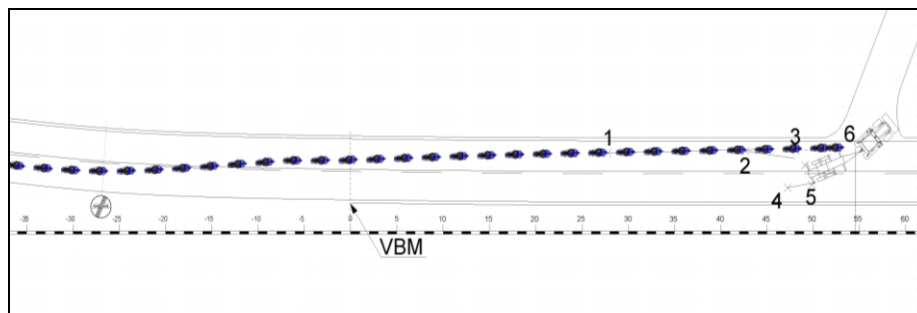


Fig. 3. Movement trajectory of the Yamaha motorcycle during the accident [14]

The movement of the tractor with the trailer can be evaluated based on the description of its movement from the witness statements, the brake mark left by the right wheel of the trailer and the documented final position of the tractor. It follows from the witness statements that the tractor should have slowed down to  $20 \text{ km}\cdot\text{h}^{-1}$ , traveled approximately 100m and then started to turn left, off the road. Before the turn, it was located with the left wheels near the center of the road, where it moved before starting the turn from the right edge of the road. After calculating the speed course, it can be concluded that the tractor was not intensively braked to the final position, while the braking was interrupted (or the tractor stopped) and its further short movement to the final position occurred.

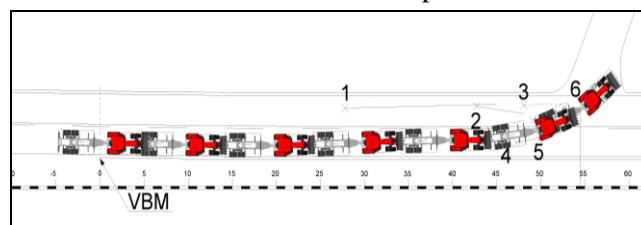


Fig. 4. Trajectory of movement of the tractor with a trailer during the accident [14]

#### Evaluation of drivers' driving technique

**The tractor driver** was driving in the right lane of the Class I road at a speed of about  $30 \text{ km}\cdot\text{h}^{-1}$ . At the time of the accident, he was making a left turn to a place off the road (forest road). He started making the turn about 2 seconds before the moment when he narrowly missed the Suzuki motorcycle,

or about 3 seconds before the Yamaha motorcycle hit the tractor. According to legal provisions, a driver turning left has the obligation not to endanger drivers driving behind him. The driver should have evaluated the traffic situation before starting the turn. If the tractor driver had correctly evaluated the traffic situation, then he would have recognized that the motorcyclists were moving in the left lane and ahead of the column of vehicles driving behind him. Motorcyclists riding behind him would not be endangered if the tractor driver started turning only after the motorcyclists had passed. **During the accident**, the driver of the Suzuki motorcycle was driving on the Class I road and was ahead of the slower-moving column of vehicles. While overtaking, he smoothly accelerated to a speed of about  $85 \text{ km}\cdot\text{h}^{-1}$ , which was not a speed higher than the maximum permitted speed for the given section, namely  $90 \text{ km}\cdot\text{h}^{-1}$ . According to the calculations carried out, it follows that the driver of the Suzuki motorcycle could have started crossing into the left lane at a moment of approx. 1.8 seconds before the start of the tractor turn. At that time, he was already at a distance of approx. 10m behind the traffic sign “end of no overtaking” and approx. 21m behind the rear of the tractor in the left lane. **During the accident**, the driver of the Yamaha motorcycle was driving on the Class I road and was ahead of the slower moving column of vehicles. While overtaking, he smoothly accelerated to a speed of approx.  $81 \text{ km}\cdot\text{h}^{-1}$ , which was not faster than the maximum speed allowed for the given section, namely  $90 \text{ km}\cdot\text{h}^{-1}$ . According to the calculations carried out, it follows that the driver of the Yamaha motorcycle could have started crossing into the left lane at a moment of approx. 0.7 s before the start of the tractor turn. At that time, he was already at a distance of approx. 7.5 m behind the “end of no passing” traffic sign and approx. 40 m behind the rear of the tractor in the left lane.

## Conclusions

According to the results, it can be concluded that the driver of the Suzuki motorcycle could have prevented the traffic accident by reacting in time and correctly (brake intensively) to the movement of the turning tractor. At the moment of recognizing that the tractor is turning left, it would move at a speed of up to  $50 \text{ km}\cdot\text{h}^{-1}$ . The driver of the Yamaha motorcycle could have prevented the traffic accident by reacting in time and correctly (brake intensively) to the movement of the turning tractor. At the moment of recognizing that the tractor is turning left, it would move at a speed of up to  $71 \text{ km}\cdot\text{h}^{-1}$ . The tractor driver could have prevented the traffic accident if he had correctly assessed the traffic situation behind his vehicle before starting the turn. At the time of the beginning of the turn, he could recognize the movement of motorcyclists in the left lane, while the first of them was already in front of the tractor. In view of this fact, the tractor driver would perform the turning maneuver only after the motorcyclists had completed overtaking the convoy of vehicles. The cause of the traffic accident was the incorrect driving technique of the tractor driver, who started to turn left (off the road) despite the fact that the traffic situation behind him was not suitable for this, which created a collision situation with the risk of motorcyclists driving behind the tractor. Before the tractor turned, the motorcyclists were moving in a section where the shape of the road and traffic markings did not prevent them from performing an overtaking maneuver. The driver of the Suzuki motorcycle was moving smoothly at a speed of about  $85 \text{ km}\cdot\text{h}^{-1}$ . He began to overtake the convoy of vehicles at a moment approx. 1.8s before the start of the tractor turn, when he was already approx. 10m behind the traffic sign “end of overtaking” and approx. 21 m behind the rear of the tractor in the left lane. The driver of the Yamaha motorcycle was moving smoothly at a speed of approx.  $81 \text{ km}\cdot\text{h}^{-1}$ . He began to overtake the column of vehicles at a moment approx. 0.7 s before the start of the tractor turning, when he was already at a distance of approx. 7.5 m behind the traffic sign “end of overtaking” and approx. 40m behind the rear of the tractor in the left lane. The tractor driver was driving in the right lane of the road at a speed of about  $30 \text{ km}\cdot\text{h}^{-1}$ . He started turning to the left about 2 seconds before the moment when he narrowly missed the Suzuki motorcycle or about 3 seconds before the Yamaha motorcycle hit the tractor. The driver could have prevented the traffic accident if he had correctly assessed the traffic situation before turning. A group of motorcyclists (X1, X2, X3, X4, X5) was in the left lane and ahead of the column of vehicles, while the first motorcyclist was already in front of the front of the tractor. The tractor driver would thus make a left turn only after completing the overtaking of the convoy of motorcyclists. As part of the analysis of a traffic accident involving an agricultural vehicle (a tractor with a trailer) and motorcyclists, it can be concluded that in order to minimize traffic accidents and their consequences, a comprehensive approach to all components of the road system is necessary, which makes it possible to reduce the role of agricultural vehicles as a hazard in road traffic.

### Author contributions

Conceptualization, M.R. and P.K.; methodology, L.M.; software, P.K. and M.R.; formal analysis, L.M. and M.B.; data curation, L.M. and M.B.; writing – original draft preparation, L.M. and M.B.; writing – review and editing, P.K. and M.R.; visualization, M.B.; project administration, L.M.; funding acquisition, P.K. All authors have read and agreed to the published version of the manuscript.

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