

Scenarios and causes of rollover incidents with self-propelled agricultural machinery in Austria

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Abstract: Rollovers are the most common incidents with tractors, self-propelled harvesting and agricultural materials handling machinery in Austrian agriculture. The precise identification of rollover incident scenarios and causes with these vehicles is the aim of the study. In order to achieve this, incident victims were interviewed and incident reports were analysed. To derive information from report and interview material the qualitative content analysis was used. The analysis showed that rollovers with tractors, self-propelled harvesting machinery and materials handling machinery showed similarities in terms of causes, circumstances and consequences although they are quite different in vehicle concept, operation and use. The rollovers were mostly influenced by the work tasks and the environmental conditions. Incorrect or inappropriate vehicle use by the driver and technical defects were also important incident causes. It was possible to work out seven conjoint main causes and 15 subcauses that were categorized in a structured class system.

Keywords: incident, agricultural machinery, rollover, victim survey, content analysis

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1 Introduction

Tractors, self-propelled harvesting and agricultural materials handling machines are the most commonly used agricultural vehicles in Austrian agriculture. Preliminary studies showed that the most frequent incidents with agricultural vehicles in Austrian agriculture between 2008 and 2010 were rollovers. Tractors, self-propelled harvesting and agricultural materials handling machines indicate similarities in main rollover incident scenarios (Mayrhofer et al., 2012; Mayrhofer et al., 2013).

The machine rollover is the leading cause of deaths or injuries related to agricultural work (Monarca et al., 2013). Tractors are associated with more fatalities than any other piece of machinery in agriculture, with tractor rollovers being the most frequent scenario (Jones et al.,

2013). Italian statistics indicate that self-propelled harvesting machines are also involved in rollovers in increasing numbers, especially caused by their high overall mass, their high centre of gravity and their development of high torque values (Pessina and Facchinetti, 2013). A third of all tractor incidents happen due to stability problems. This occurs when the angle of the slope is greater than the rollover angle. A rollover happens within 1.5 seconds. It is impossible for the driver to avoid it, no matter how experienced he is (Özdes et al., 2011).

Rollovers with material handling machinery play an important role in construction, for example rollovers were the most frequent nature of incident among forklifts in the United States (Bedford, 2006). Forklift trucks, dumpers and telehandlers (telehoist load luggers) are - due to the high centre of gravity - especially at risk for rollovers. Working on uneven ground, on slopes or with poorly distributed loads lead to incidents because of stability problems (EU-OSHA, 2000). As with many other vehicle incidents, the speed is mostly the decisive factor

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for rollover incidents (Horberry et al., 2004).

Investigations by Gattamelata et al. (2012) showed that a large number of self-propelled harvesting machines are used on hilly terrain, both in arable and in grassland farming. In slightly (to 20°) and medium steep slopes (20°-35°) in arable farming self-propelled combine harvesters, potato and sugar beet harvesters are used. Above 35° slope, there is mostly grassland farming with two axle mowers and transporters. Hilly vineyards and terraces are also a typical environment of rollover incidents involving farm machinery (Ferrari and Cavallo, 2012).

The application limit of agricultural vehicles is subject to many factors. In addition to the slope, and the uniformity of the surface, the presence of reversing and alternative driving options near the steepest places is an important factor. For the safe use of machines in grasslands as well as in arable land the botanical composition of the turf and the soil moisture content are critical (Sauter and Krawutschke, 2008).

In preliminary studies, an incident database from the Austrian Social Insurance Institution for Farmers was analysed. Based on database information from 2008 to 2010, the identification of safety and information deficits responsible for rollover incidents and the sustainable development of prevention measures were not possible. The causes and particularly the incidental human-machine interactions could not be revealed from the database. These knowledge gaps can be closed by interviewing victims and by analysing incident reports that were filled out by the victims to obtain insurance payment. Therefore, the precise identification and presentation of incident scenarios and causes of rollover incidents with tractors, self-propelled harvesting machinery and agricultural materials handling machinery in Austrian agriculture is the aim of the study. It is essential to find out the interaction between the machine and the driver during the rollover incident, especially for the derivation of effective prevention measures in further investigations. The chosen machinery types are the most commonly used agricultural vehicles which indicate similarities in main incident scenarios, indicated by press reports. By simultaneous investigation of three different

vehicle types, more detailed causes and scenarios can be identified.

2 Materials and methods

The Austrian Social Insurance Institution for Farmers provided anonymized copies of incident reports in paper form. This material was digitally stored at this institution because it was submitted by the victims of occupational incidents with tractors, self-propelled harvesting machinery or materials handling machinery between 2008 and 2010.

In Figure 1 the procedure for identifying incident causes and scenarios is presented. Rollover incident reports were analyzed by a qualitative content analysis to obtain detailed information about the scenarios and causes. There were 97 reports report analysed by the qualitative content analysis. Some information deficits about the scenarios and causes were given, and the main reason were incompletely filled out reports by the victims. In these cases, questioning of the incident victims could remove these deficits which were conducted.

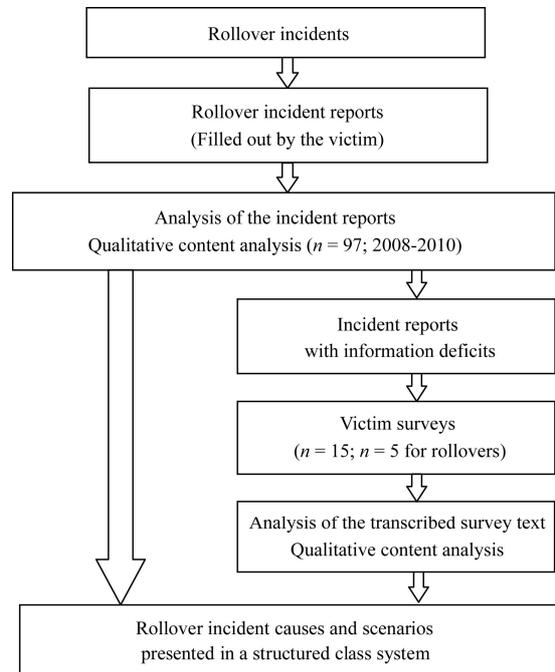


Figure 1 Flow diagram of material and methods

The aim of this survey was to obtain missing information on the incidental human-machinery-interaction by questioning of the victims. Before designing the questionnaire, previously performed incident victim surveys of Prodingler (2011), Gründl

(2005), Kirchoff et al. (2008), Könnecke (2007), Bartl and Hager (2006), GDA (2008) and IAREH (2001) were evaluated. The questionnaire was constructed based on this evaluation and on the lack of information from the qualitative content analysis of incident reports. A semi-standardized interview schedule was chosen, which was completed by the interviewer in person during a private conversation with the respondents. The questionnaire consisted of qualitative and quantitative questions with six thematic sections about the victim, farm, incident vehicle and site, working process (task), scenario and cause of the incident and recommendations of prevention.

The qualitative and quantitative questions of the questionnaire were evaluated differently. For the quantitative evaluation of the questions, the answers from the interviews were entered into a database and analysed descriptively. Due to the small sample size no statistical analytical testing was done. As a result of the quantitative evaluation, the observed frequencies and percentages were reported in the results.

For the qualitative evaluation, digital protocols of the interviews were transcribed. The transcription of the data was performed with the aid of the freely accessible f4 software program. The f4 software helped to transcribe audio data such as interviews by a flexible playback speed and by repeating the last words after transcription breaks, which improved the flow of the write-up. The transcription rules were the transcription in standard orthography and the abandonment of a literary inscription, the non-transcription of non-verbally and non-endorsements and interruptions in conversation and noises observed (Gläser and Laudel, 2010). The texts of the victim surveys transcribed were processed in the qualitative content analysis.

With a literature and internet research on Mayring (2008), Gläser and Laudel (2010), Luria and Yagil (2010), Larcher and Vogel (2010) and Matscher et al. (2007), the qualitative content analysis was chosen in order to extract and categorise information from both the incident reports and the transcribed interviews to identify incident scenarios, causes, etiological factors of rollover incidents and similarities between tractors, self-propelled

harvesting machinery and material handling machinery. The incident reports and the transcribed interviews were systematically evaluated according to standardized rules. A systematic rule-governed process for the study of human expressions in written and spoken form is the qualitative content analysis (Mayring, 2008). The qualitative content analysis corresponds to an interpretation process. The qualitative content analysis of the text material compacts messages by paraphrasing, generalizing and abstracting according to a complex system of categories, which allows the reduction of the content to the main facts and the extraction of the necessary information on the human-machine interaction in an incident (Mayring, 2008). In the content analysis the incident reports and the transcribed interviews were read and it was decided the assignment of information to the sub causes. No relevant text parts were removed. Important information was summarized on a single language level. Before new phrases were assigned to a category, it was examined if a similar statement has already been recorded. Phrases with the same content and unimportant components were deleted.

New categories were supplemented during the extraction to the existing categories of the theoretical considerations if new relevant information appeared. For review, the contents of the category system were checked on the raw material by sampling on its accuracy on Mayring (2008). The qualitative content analysis was performed manually with existing software programs.

For a clear presentation of the results a structured class system was developed with so-called incident main causes and sub causes. The seven main rollover causes and 15 sub causes are given in Figure 2.

The main causes were developed in Mayrhofer et al. (2012) and the sub causes were supplemented with the qualitative content analysis. In the results, the information of the analysed incident reports and transcribed interviews was summarized for each main cause. This meant that the processes and causes of the sub-causes were reconstructed to represent the incident triggering causal mechanisms (Gläser and Laudel, 2010). The results of the extractions were combined for each main cause in a way that the image of the base material

remained. In the results each main cause was shown in the same way. Firstly, it was pointed out with which machines rollovers occurred during the evaluation period.

Secondly, the most important examples were presented descriptively. The level of details of the results depended entirely on the quality of the source materials.

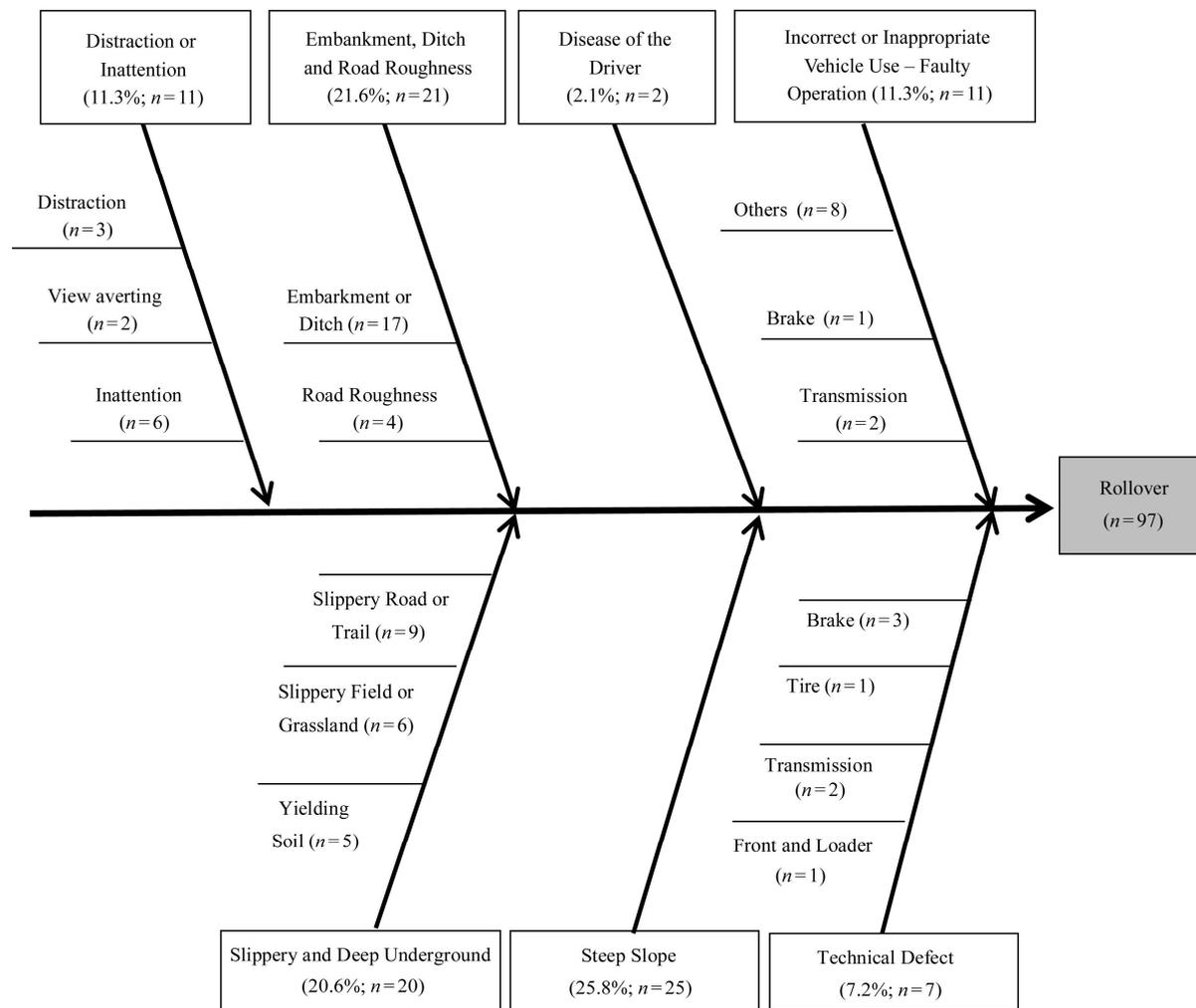


Figure 2 Category system for incident causes

3 Results and discussion

In total 15 victims were interviewed, 12 of them (80.0%; 12/15) had a tractor incident, two (13.3%; 2/15) had an incident with a small wheel loader and one with an excavator. Nine victims were managers (60.0%, 9/15), three were spouses or wives (20.0%, 3/15) and two were the parents of the manager (13.3%, 2/15). One incident victim was the son of the manager. More than 80% were over 40 years old (85.7%, 12/14). Only two persons were under 40. Regarding the farm, the surveys showed that two-thirds (66.7%, 10/15) were conducted in full-time employment. The remaining third was reported as part-time farming. The farm size was in 40% (6/15) of the cases between 21 to 40 hectares

agricultural land. A third of the farms cultivated (5/15) less than 21 hectares and a little more than 10% (13.3% 2/15) had 41 to 60 hectares.

Generally, slightly more than half of the incidents (53.3%; 8/15) were rollovers. In five cases a person was run over and in two cases a person was trapped. Concerning the machine-related incident causes, there was just one victim (6.7%, 1/15) whose machine had a technical failure which caused the incident. On the questions related to the human causes of incidents 7 of 13 respondents said they made an error during driving or operating the vehicle, which caused or influenced the incident negatively. This was more than the half (53.8%, 7/13). The remaining participants stated that they did not make a mistake in the situation just before and during

the incident that aggravated the outcome of the incident (15.4%, 2/13).

In term of environmental causes of incidents information was collected about weather, slope and soil conditions of the incident site. To the incident site nearly 30% (26.7%, 4/15) of the respondents said that the incident happened on fields or grassland. A third (33.3%, 5/15) of them occurred on roads, 20% (3/15) in the barn or on the farm, and just over 10% (13.3%, 2/15) occurred in the forest or woodland. In two thirds of the incidents (66.7%, 10/15), it was sunny, in two cases cloudy or dark and in one case snowing. According to the information of the respondents in 2 of 15 incidents, the weather had a negative effect on the incident.

Looking at the terrain slope, the interviews showed that more than 70% of the incidents (73.3%, 11/15) happened in areas slightly or strongly inclined. In 9 of these cases the terrain slope affected the incident negatively. Only 4 of the 15 surveyed incidents occurred on flat terrain. In two thirds of the incidents the ground was dry (66.7% 10/15), in four cases it was slippery (26.7%, 4/15) and in one it was uneven (6.7%, 1/15). In five cases, the soil conditions influenced the incident negatively.

As presented in Figure 2, there were seven incident main causes and 15 sub causes triggering rollover incidents with tractors, self-propelled harvesting machines and material handling machinery. The three most common incident causes related to the environment. The most important rollover cause was the steep slope with about 26% (25.8%; 25/97). The second most common rollover incident causes were with a bit more than 20% (21.6%; 21/97) embankments, ditches and the road roughness. Slippery and deep underground also played an important role (20.6%; 20/97). These incident main cause category included rollovers caused by slippery roads, trails, fields or grasslands and by a yielding soil. Causes of incidents relating to the driver were with 11.3% (11/97) on the one hand distraction, inattention or view averting and on the other hand incorrect or inappropriate vehicle use. In this main cause a distinction was made between the faulty operations of the break, the transmission and other

different tasks. Technical defects played a minor role with 7.2% (7/97). There were defects of brakes, tires, transmissions and of front end loaders.

The detailed descriptions of the rollover incident causes are presented in the following section. The incident main cause disease of the driver is not described in detail, because it was in one case micro-sleep and in the other case a problem with the blood circulation.

3.1 Distraction or inattention

Under this category rollovers are summarized that arose by personal distractions and carelessness. In this category rollovers happened with all investigated machinery types. They occurred in different agricultural and forestry works. For example, during driving on the road with the tractor a drinking bottle fell from the provided holder, the driver was distracted, ran off the road and the vehicle rolled over sideways. The driver of a two axle mower was stung by a wasp during mowing. As a result the driver shifted in the wrong gear, went off the planned direction and turned over. View averting also played a role during driving. In two investigated cases a tractor deviated from the road because the driver looked back to the attached device or load during the ride. In four investigated cases tractors deviated from the road because of carelessness. They came on the roadside and rolled over. In one case a skidding tractor rose up in the front with the winch due to a trapped tree trunk and the tractor turned over sideways. In summary, the results show that rollovers appeared due to inattention or distraction in various activities. These incidents were highly individual, even within the machine type, influenced by the work tasks carried out.

Olejnik (2005) who investigated agricultural tractor driver's limitations of visual transmission in aspect of road safety in Poland pointed out that the agricultural machines are vehicles whose drivers have to receive information from their environment to drive consciously and safely for their selves and the other participants of road traffic. Attention without any distractions is crucial. While most experienced tractor operators have developed an intuitive feeling in perceiving hazardous situations, there are many inexperienced young or casual workers who have no specific training in driving the tractor safely

(Nichol et al., 2005).

3.2 Embankment, ditch and road roughness

In this cause category, rollovers were categorized that appeared on or near embankments, ditches and rough roads. Embankments and ditches are along roads and paths as well as on or near meadows, fields and forests. Both with tractors and self-propelled harvesting machines as well as together with load transportation machinery rollovers happened in this category. For instance, driving tractors on a street or road led to a rollover during reversing and going downhill near path edges and embankments. For example, a farmer drove a tractor with an attached front rake on a trail. A car came towards the tractor, the driver could not escape in time and rolled over on the road embankment. Because of the front rake the load on the rear axle was not sufficient for enough braking force. In two cases, clearing snow was responsible for tractors overturning over an embankment. In one case, the victim stated to have taken too much heavy snow with a front loader. The tractor was not ballasted accordingly, slid sideways and overturned in a road cutting. In another case, the incident happened at plowing with a two-furrow plow along an embankment edge. Because the farmer had to drive outside the edge to draw an exact border furrow, the tractor slipped with the wheels through the embankment and turned over. By evasion of grazing livestock at feeding, charging of manure and mowing, tractors came too close to embankments and turned over. The sub-cause road roughness was exclusively associated with small wheel loaders and two axle mowers. In one case, the small wheel loader was used in forestry work in steep terrain. At lifting a tree, the small wheel loader ran with a front tire into a hole that the driver did not see and which caused a rollover. An incident with a similar man-machine interaction occurred on a fruit garden meadow. As a cause in another wheel loader incident, the driver lost charged silage during transporting. The wheel loader drove over it and tossed around. As a conclusion, the rollovers near embankments and ditches as well as on rough roads showed similarities - although they happened with different machines at various agricultural or forestry tasks.

Crucial for the safe use of vehicles in the mountain area is the comprehensive knowledge of the terrain conditions (Huber, 2010). Jones et al. (2013) studied trends in tractor related fatalities among adults working on farms in the Australian state Victoria from 1985 to 2010 and found out that most rollover cases involved driving the tractor on steep embankments. The most common cause of sideways rollovers was the result of driving too close to the edge of a steep slope, usually a ditch by a public roadway or a field, and this usually occurred during transportation or field work (De Groot et al., 2011).

3.3 Incorrect or inappropriate vehicle use – Faulty operation

Operation errors happened with every investigated machinery type. Incorrect or inappropriate vehicle use summarized rollovers that happened because of an incorrect operation of the machine. The most important causes were errors in the operation process of the incident victims. Two rollovers with tractors appeared because of incorrect or inappropriate shifting. In the first case, the tractor ran backwards unplanned by a switching mistake in forestry work. This faulty operation resulted in correspondingly hilly terrain to a rollover. Another incident happened during driving a tractor with slurry tanker in a steep meadow. During the switching process (downshifting the powershift stage), the wheels blocked in the relevant human-machine interaction. The weight of the slurry tank and because of the jerk at the switching process, the vehicle combination went into a slide and overturned on the steep slope. For an incorrect use of the brake, there was reviewed one rollover example, during driving the tractor; the driver mistakenly operated the steering brake which caused the tractor running off the planned direction. The tractor overturned on an embankment. Beside this special sub causes, many different mistakes or inappropriate vehicles uses led in single cases to rollovers. For example, the operation from outside the cab led to a forklift rollover. For tip or rollover with tractors or small wheel loaders, incident victims reported, that they turned in too much or too quickly. This happened among others during sliding in manure or lifting boxes. For example, through the

confusion of pedals a small wheel loader drove backwards unplanned, whereby the vehicle with a driver crashed into an adjacent pond. As a result it must be stated that the possibilities of making machinery operating errors were endless. Although, the incidents were organized in different sub causes like incorrect use of brake or shift, these incidents were highly individual, even within one machine type.

After Rondelli et al. (2013) safe vehicle operation also depends on operator skills, like driving experience and reaction time. Interacting factors affect the operator's perception of hazard, using his skill and intuition to evaluate the effects of different environmental factors. Furthermore, the ability to operate safely is further reduced by adverse stressors as vibration, noise, cold and heat and this is particularly significant when stressor conditions drag on as occurs frequently during farming.

3.4 Slippery and deep underground

In the reports or the interviews were mentioned main rollover incident causes generated by slippery or deep underground. This cause category involves on the one hand wet pavement, ice, sludge and rubble on roads (slippery underground) and on the other hand wet soil without loading capacity (deep underground). Rollovers happened in all investigated machinery types because of slippery or deep underground. This cause has to be also associated together with other incident causes that influenced the incident negatively. For example, rollovers happened due to slippery roads and paths both with tractors and wheel loaders. With small wheel loaders exclusively frozen ground conditions have been specified, leading to a rollover. By slippery surfaces, the braking and handling of the vehicles were affected so negatively that they came off of the intended driving direction and rolled over. Especially, with old compact tractors and small wheel loaders in sloping terrain a small amount of rubble was enough to bring the vehicle in incident risk. Particularly, in the context of a lack of driving experience, slippery surfaces led to dangerous human-machine interactions. A wrong reaction to spin and a crash was inevitable. Rollovers due to slippery surfaces on fields and meadows occurred mainly due to

wet soil conditions. These incidents happened mainly with tractors and transporters. In one case, hay was identified as significant cause of incidents. Rollovers due to slippery surfaces should be considered in conjunction with steep slopes. In the incident causal man-machine interaction, the vehicles came from the direction of travel planned, the vehicle driver could not react accordingly and the rollovers occurred. Rollovers with tractors due to a deep underground happened beside ways, in forests or fields, especially during the tillage. During construction, rollovers occurred both with an excavator, as well as with a transporter. In both cases, the vehicles sank in the deep earth underground. The majority of the incidents took place in the context of deep underground on embankments and slopes. Because of the large number of cases with a sudden yielding of the soil, the vehicle operators could not react in the relevant human-machine interaction and an incident was inevitable. Finally, the results of this category show similarities in incident circumstances beneath all machinery categories. The effects on the driving behaviour of a slippery underground were underestimated or misjudged.

Tractors are often used on banked, uneven, soft and slippery ground. Difficult terrains such as these can often result in reduced adhesion between the tractor tyres and the ground causing a loss of control by the operator, and even lateral rollover of the tractor (Baker and Guzzomi, 2013). After Mashadi and Nasrolahi (2009) the stability loss on rough ground is more likely than on deep or smooth ground because the wheels of a tractor follow the bumps and hollows of the rough ground and cause steep local slopes. The general ground slope may be small, but ground roughness causes local slopes to become steep. Major critical variables reducing tractor stability are slopes and rough terrain; these factors interact in a complex manner in determining the risk of rollover, influenced by the position of the tractor's centre of gravity, forward speed and turning angle (Rondelli et al., 2013).

3.5 Steep slope

In this incident category, the rollovers with a steep slope as the main incident cause were summarized.

Steep slopes were encountered in fields, meadows, forests and on roads or paths. In the relevant human-machine interaction of the incidents, the interaction with other causes (such as slippery surfaces or yielding soil) was decisive. In rollover incident reports with tractors in tillage, seed or maintenance work, the slope or gradient was specified in most of the cases. In a rollover incident with a tractor, the steep slope was mentioned in combination with a bump and in three other cases steep slopes in combination with driving errors in turning or reversing. In one particular case, the vehicle combination of tractor and round baler was oversized for the application situation. The farmer worked in wet driving conditions at night and in the relevant human-machine interaction the terrain was too steep in order to prevent the incident. At rollovers in liquid and solid manure spreading tasks with tractors, in most cases only the slope or gradient was specified. In three cases, the pushing or pulling action of the slurry tank was specified on a slope. In each case of a rollover in the wine and fruit garden - with tractors and forklifts – the slope was not mentioned in detail. In summary, rollovers on steep slopes showed similarities, although they appeared with different machines at various agricultural or forestry tasks. The technical equipment of the vehicles plays a major role.

Tractors are often operated on uneven terrains with varying slopes (Liu and Koc, 2013). Tractor rollover on slopes is a significant cause of fatalities in tractor incidents (Baker and Guzzomi, 2013). The majority of agricultural tractor rollover incidents on slopes are of two types. The first, known as a stability loss incident, is when the tractor overturns directly, and the second, known as a control loss incident, is a running way of tractor by out of control before overturning (Owen and Hunter, 1988). Another common cause is driving across a steep slope or an incline in such a way that the machine goes beyond its stability baseline and overturns (DeGroot et al., 2011). It is shown that the stability of a tractor depends on the position of the centre of gravity of the main posterior body (Baker and Guzzomi, 2013)

3.6 Technical defect

Technical defects causing the rollovers were

recognized only for tractors. Different defects were reported and organized in different sub causes, by the engine parts like brake or tire. The most frequent ones were defective brakes. Such incidents occurred on slopes and are therefore to be considered in relation to this cause. In one tractor incident the brakes overheated excessively and in another the brakes blocked. The overturning could be caused by a wrong maneuver or given road course. In one examined case, the hand brake dissolved during the repair work at an attached machine. The tractor rolled away and turned over. In two tractor rollovers a transmission defect was indicated as the main incident cause. In one example, the switching operation was not possible, and in another case, during braking, the throttle of the tractor was under the set throttle level. For the tractor gearbox, a certain throttle level is necessary that the oil pressure in the transmission is maintained, the gearbox and the wheel turned to neutral. The vehicle accelerated on the steep road, the braking action on the rear axle was not enough, the driver relented wrong and the vehicle rolled over several times. The technical defects were different in every machine category. In further investigations potential prevention solutions must be developed individually for every technical defect of each machine type. The pooling of vehicles for the prevention determination of this cause category is not possible.

Technical defects generally arise as a result of poor maintenance practices. McGwin et al. (2000) showed in his studies that higher injury rates for farmers using farm equipment in poor condition. Poorly functioning vehicles place farmers at incident risk. Machinery in poor condition may require more maintenance and repair than properly-functioning machinery, which adds to risks. After Bunn et al. (2008) in Kentucky the lack of tractor maintenance was identified as a human factor in 10% of the agricultural tractor fatalities. The lack of tractor maintenance and the lack of brakes or clutches were contributing factors that were significantly associated with fatal injuries. This problem may be more common in older tractors. Insufficient or inadequate safety equipment contributed to the incident in 14% of the incident cases with tractors in Finland. But in Finland,

the condition and safety features of incident tractors proved to be better than those of all tractors in the data (Suutarinen, 2003).

Overall, by the material and method selected, it was possible to reconstruct main rollover incident causes based on incident reports and interviews with incident victims that were processed with the qualitative content analysis. The result of the analysis depended on the quality of information of the incident reports and the thematic interviews. The classification of the incidents into categories was always done according to the main reason given by the victim. Concerning a detailed human-machine interaction, the victims did not go very much into details during interviewing. They mostly described the course of events, but not the causal interaction of the incident, they could not remember the exact sequence of actions in the human-machine-interaction, and they could not express the details in words or displaced the incident and its consequences. In many incidents investigated by reports and interviews only one cause was specified.

A disadvantage of the qualitative content analysis was that the text had to be interpreted and assigned. Whether certain information is contradictory or redundant, it depended on the individual understanding of the scientist. Further, the openness of the qualitative content analysis should be seen critically, because a certain sub-assumption cannot be avoided.

An advantage of the qualitative content analysis was the fact that information was extracted from texts, without taking into account the position in the incident reports and was processed separately from it. Furthermore, the entire information was treated equally and was cleared after reading each section, if relevant information was included. The aggregation of the machine categories in the analysis offered the benefit that a larger number of incidents could be examined. By parallel investigation of rollovers of different vehicle types, detailed causes and scenarios could be identified in a more efficient and effective way.

4 Conclusions

The vehicle rollover is the most important incident scenario with tractors, self-propelled harvesting machinery and material handling machinery. Based on incident reports and interviews with incident victims the qualitative content analysis was used the first time to identify incident scenarios, causes, etiological factors of rollover incidents and similarities between tractors, self-propelled harvesting machinery and material handling machinery. The incident reports and the transcribed interviews were systematically evaluated according to standardized rules of a qualitative content analysis. There were seven main rollover causes and 15 sub causes that were shown in a structured class system and that were described in detail in this paper. It can be seen at a glance which rollover incident causes appeared with tractors, self-propelled harvesting machinery and material handling machinery. The materials investigated were incident reports from the years 2008 to 2010 in Austria. For these three years, a variety of incident types is covered by this sample, but conclusions for all rollover incidents in Europe cannot be drawn. In summary, through the qualitative content analysis in combination with the results of the preliminary investigations, detailed information on incident scenarios, causes and etiological factors, particularly related to human-machine interaction is available now in order to further develop consisting preventive measures for rollover incidents. In the derivation of incident prevention measures, it should be examined which preventive measures are provided by important International Standards, European Standards and the European Machinery Directive. In further steps manuals of new machinery should be analysed to find out which information is provided for the user concerning incident prevention. The prevention measures should be established, as defined, on the current state of the art and on future potential innovations together or separately for the different machinery categories.

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