

## **A Risk Assessment Procedure for the Users of Narrow Track Tractors**

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### **Abstract**

**The impact of the introduction of the directive 2006/42/CE in EU Countries is quite significant for companies, both users and producers, because of the new Essential Health and Safety Requirements (EHSRs), as well as due to the extension of its scope. In such a context, the research work presented in this paper is focused on the field of machines for agriculture, and in particular tractors. Starting from the analysis of accidents occurred in the sector, the study was aimed at bringing to light the aspects which must be investigated by using the new Machinery Directive approach while performing the risk assessment activities, focusing the attention on the users' behaviour.**

**Keywords:** occupational safety, machine directive, risk assessment, agricultural tractors

### **Introduction**

Standards and regulations concerning occupational health and safety have become more and more severe in last decades. Despite this, in EU countries the number of accidents and victims has not significantly decreased. According to official statistics, the situation is particularly critical for small and medium sized enterprises (SMEs) where safety regulations are more difficult to be applied: in Italy, agriculture sector is certainly one of the most affected by this situation, especially taking into account the occurrence of serious injuries and fatalities. The issue of the new machinery directive (2006/42/EC) introduced additional requisites for both machine producers and users, including agricultural tractors in its scope. On one hand such an improvement, makes the safety level of operators higher. On the other hand, the compliance with new safety requisites results in being more difficult, due to the specific characteristics of the sector. Actually, the large variety of activities usually carried out by companies, the use of obsolete machines and equipments, as well as the continuous change of workplaces are all alone factors which make the management of agricultural activities harder to deal with.

On these considerations, the paper presents a procedure for risk assessment, which was developed with the aim of supporting all stakeholders involved in the use of tractors in being in compliance with the new regulations. The proposed approach was focused on the importance of the users' behaviour in the occurrence of accidents by means of its application to an agricultural and forestry narrow-track tractor.

### **2. Recent developments in Agricultural Safety**

Nowadays there is a growing awareness of the importance of safety in the agriculture and forestry fields: this is mainly due to the latest developments of legislation and standards in the sector, concerning both occupational and machine safety. Thus, on one hand we have to

underline the improvements brought by the introduction of the new machine directive (2006/42/CE) at EU level, and by the update of the Italian law on occupational safety. They have increased the safety level of workers, making stricter the safety requirements that have to be satisfied. At the same time, also international standards affecting machine safety have been improved recently, and in particular the ISO 14121:2007 standard, concerning risk assessment procedures resulted in being very significant.

On the other hand, difficulties related with the implementation of safety measures are numerous, in particular for small and medium sized companies (SMEs), which can not afford additional costs for the compliance with these safety requirements. As a matter of fact, SMEs represent more than the 80% of enterprises operating in the agricultural sector, and most of them are very small sized, run by family members. Beside this, we also have to consider the fact that there is a large number of part-time workers, who are involved in agricultural activities in their spare time, and for this reason they are not registered as farmers, avoiding in this way to fall under the scope of the above mentioned legislation.

With the aim of bringing to light the main aspects of the situation, it is also necessary to analyze accidents which occurred recently in the sector.

Latest data concerning the occurrence of occupational accidents in the sector of agriculture show that the problem is very relevant in Italy both considering its absolute value, and taking into account accidents which have occurred in agricultural activities compared to sectors of other activities. On the basis of data published by INAIL (Italian Workers' Compensation Authority), in Table 1 the comparison of accidents which occurred in agriculture and industry sectors is shown [INAIL, 2010].

**Table 1. Accidents which occurred in agriculture in Italy.**

<b>Injuries</b>							
<b>SECTOR</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>
<b>Agriculture</b>	71.379	69.263	66.467	63.083	57.206	53.354	52.629
<i>difference with previous year (%)</i>	-2,9	-3,0	-4,0	-5,1	-9,3	-6,7	-1,4
<b>Industry</b>	456.333	446.210	422.254	413.375	400.103	366.159	297.290
<i>difference with previous year (%)</i>	-2,7	-2,2	-5,4	-2,1	-3,2	-8,5	-18,8
<b>Fatalities</b>							
<b>SECTOR</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>
<b>Agriculture</b>	128	175	141	124	105	125	125
<i>difference with previous year (%)</i>	-23,4	36,7	-19,4	-12,1	-15,3	19,0	0,0
<b>Industry</b>	763	673	616	678	611	532	490
<i>difference with previous year (%)</i>	5,4	-11,8	-8,5	10,1	-9,9	-12,9	-7,9

In fact, in last year a minimum decrease of the number of accidents was achieved (-1,4%), but this is not so significant if we consider the number of workers operating in the sector, i.e. the frequency factor (number of accidents per 1000 of employees). And most of all, the number of fatalities has not changed at all.

Analyzing these data from the “material agent” point of view, it emerged that in agriculture the most dangerous sub-sector (e.g. considering the number of permanent injuries and fatalities which occurred) is represented by the activities which involve the use of machines and mechanical equipments, and in particular tractors. Data collected by ISPESL (National

Institute for Occupational Safety and Prevention) show that in 2008 a number of 169 accidents related to the use of tractors occurred, causing 114 fatalities. In 2009, 257 cases of serious injuries were registered, and among them 149 cases led to the operator's death. In both cases the number of accidents related with the use of tractors resulted in being very large: 212 workers injured and 126 fatalities. At this point it has to be underlined the fact that since 1993 in Italy the Compensation Authority does not include in official statistics accidents occurred to self-employed workers. For this reason, the real number of accidents registered taking into account reports of both police departments and inspectors of the national health service is different from official statistics for compensation.

Furthermore, also accidents occurred on the road were considered: in the period May 2009-April 2010, according to ASAPS [ASAPS, 2010], 296 cases involving tractors were registered, causing 174 fatalities among tractors' drivers and passengers. As emerged from previous studies [Fargnoli et al., 2010], the main reasons of such a situation can be found in the following aspects:

- technical obsolescence of tractors, i.e. the age limit over which the machine starts losing its technical efficiency and functionality is estimated in 15 years;
- a large number of machines used in agricultural activities are not up-dated following the recent development of safety standards and regulations;
- the number of workers specifically trained for the use of tractors and agricultural machinery is very small.

This is particularly true at an operative level: the lack of knowledge and expertise in both risk assessment and safety management is significant also because of the large number of part-time operators, elderly or foreign workers, who have rarely received professional training for the activities they are asked to perform. In particular, information concerning safety instructions of different working tasks and the use of PPEs (Personal Protection Equipments), difficulty in keeping the company in compliance with up-to-date laws and regulations, as well as hindrances in carrying out the regular maintenance of equipment and safety devices (which are often very old and obsolete), are quite common in the sector, as also underlined by several authors (e.g. [Schenker and Orenstein, 2002]), and by the latest reports of EU-OHSA (European Agency for Safety and Health at Work).

### **3. Tractor's safety**

The analysis of data concerning accidents in the agricultural sector brought to light the importance of problems related with the use of tractors. For this reason a detailed study of safety requisites of laws and regulations affecting this kind of machinery was carried out. Among all of them, the following ones are certainly the most important:

- Tractor Directive (Directive 2003/37/EC): it defines technical requirements that all new vehicles belonging to categories T1, T2 and T3 have to satisfy following the “EC type-approval” certificate (Categories T1, T2 and T3 are defined in Annex II of Directive 2003/37/EC).
- New Machinery Safety Directive (Directive 2006/42/EC): this directive represents a significant novelty in the field. Actually, until the process of updating the Tractors Directive is completed taking into account all risks related to tractors, also tractors fall into its scope, and thus manufacturers are asked to verify the conformity of the tractor with the Essential Health and Safety Requirements (EHSRs) listed in Annex I, following the same process as traditional machines. Other relevant aspects of this law concern: the possibility of applying the full quality assurance procedure provided for in Annex X for roll-over protective structures (ROPS) and falling-object protective structures (FOPS); the need of providing a Risk Assessment Report for all the risks

currently not covered by Directive 2003/37/EC concerning agricultural or forestry tractors. Machinery mounted on these vehicles fall in the scope of the directive with no exceptions. This Directive came into force on December 29<sup>th</sup>, 2009.

- National law concerning Occupational Health and Safety (Decree 81/2008): in Italy this law was issued in April 2008 and updated in August 2009: it takes into account the safety procedures which have to be followed during all kind of working activities, the requisites which have to be satisfied by the Risk Assessment Report, the minimum safety and health requirements for the use of work equipment by workers at work, and for maintenance operations of working equipments.
- The OECD Standard Codes, which set common rules (and harmonized procedures) for the Official Testing of Agricultural and Forestry Tractors in OECD countries: usually requisites of OECD Codes are implemented in EU directives, as in the case of the recent Directive 2010/22/EU of 15 March 2010.

More in details, as emerged by the study carried out by a technical EU Commission, residual risks which are not covered by the directive 2003/37/EC are the following:

- falling objects;
- penetration of objects into the cabin;
- seat-belt anchorages for passenger seats;
- extreme temperatures;
- hazardous substances;
- users' manual.

Thus manufacturers have to issue a CE Declaration of Conformity (and affix the CE mark), declaring that these risks were taken into account in conformity with the Machinery Directive prescriptions. Another aspect which emerged from the analysis performed is the lack of specific requisites for operators, who have to work with tractors, i.e. a specific “driving licence” or mandatory training course. As a matter of fact, there is a strong relationship between safety rules for road users (established by the Italian Highway Code) and safety requirements for workers: users of agricultural or forestry tractors have to deal with general safety requirements for driving a vehicle, including the vehicle maintenance and its conformity with technical requisites. For example, the use of a tractor without ROPS is forbidden not only in working activities, but also in public roads. Furthermore, as emerged from the accidents' statistics, numerous accidents with tractors occur on the road, both when users go to or came back from working sites (“in itinere” accidents), and when they use the tractors as a normal vehicle.

#### **4. Research approach**

As emerged from the analyses carried out in collaboration with the Interregional Working Group for Occupational Safety in Agricultural and Forestry activities, the number of companies operating in the field not complying with safety requisites is still very large. The lack of safety in this sector is caused mainly by the difficulty of companies in implementing safety requirements in accordance with compulsory regulations. This is due to the specific characteristics of working activities in agriculture, such as:

- the large number of different of activities usually carried out in this sector;
- the frequent exchange of tasks among workers within the same company or the frequent exchange of workers for the same activity (e.g. seasonal workers);
- the variety of work environments, which is not easy to foresee in advance, when risk assessment is carried out (e.g. different grounds, atmospheric conditions, etc.);

- the stress caused by seasonal jobs (in some situations workers have to work continuously for a period of time which is longer than an usual shift, and this might cause stress, fatigue, tiredness, etc.).

In such a situation, even a correct application of safety requirements by company's managers might result in being less effective: spreading information concerning risk prevention and providing right procedures, which should be followed with the aim of reducing the occurrence of accidents, is certainly more difficult than in traditional industry sectors. In such a context, the development of a correct Risk Assessment Report, which takes into account also risks related with the skills of the tractors' users is fundamental. The goal of the present research work is to provide a solution to such a problem, throughout the development of a risk assessment procedure of a general nature, which can be applied in different work situations, overcoming the complexity of regulations in the sector. More in details, starting from the issues of the new Machinery Directive, a general framework for Hard Analysis (HA) activities was developed, adopting the procedure for risk assessment and risk reduction proposed in section 5.1.3 of the standard ISO 12100-1:2003 (considering also the indications of a general nature proposed by the standard ISO14121-1:2007). Starting from such this general scheme, the Risk Assessment stages were analyzed (Figure 1), focusing our attention on the residual risks for tractors, which are not considered by the directive 2003/37/EC. With this aim in mind, the analysis of a narrow-track tractor was performed. Main characteristics of the vehicle analyzed are the following: wheeled tractor with a maximum design speed of not more than 40 km/h, with a track width of 1.147 mm and length of 3.750 mm, with an unladen mass of 2.450 kg (without cabin), and an engine power of about 70 HP.

## **5. Hazard Analysis**

In order to make the Risk assessment more detailed, the following tools for carrying out Hazard Analysis activities were used. Firstly, we applied the Preliminary Hazard Analysis (PHA): this method allows engineers to bring to light most significant risks of the machine, providing a qualitative estimation of them [Clifton, 2005]. The use limits of the tractor were taken into account considering the following use phases: access to the driving position; mechanical coupling between tractor and towed equipment; use in the field; maintenance operations. Results of this analysis showed that most dangerous risks are: roll-over and rear-up tendency; use of the power take-off; improper behaviour of the user. Since the first two of the above mentioned risks concern mainly constructive solutions, whose design requisites are well established by technical standards, we fixed the attention on the third one, i.e. the behaviour of the operator.

For this purpose, the Fish Bone Diagram (FBD) method [Clifton, 2005] was used, with the aim of finding out the possible causes of the improper use of the tractor (e.g. operator, management of working activities, etc.). This application was carried out analyzing types and causes of significant and fatal accidents registered in the ISPESL accidents' database, as well as literature backgrounds (e.g. [Yadav and Tewari, 1998] and [Myers et al., 2009]). In Figure 2 an excerpt of this application is shown.

As far as the human error is concerned, according to [Rasmussen, 1983; Reason, 1990], the main causes can be found in:

- a skill-based behaviour (automatic, unconscious and used to perform a task in parallel with other activities), which usually leads to slips, i.e. misapplied competence;
- a knowledge based behaviour (used to solve problems consciously), leading to mistakes generated by lack of knowledge;
- a rule based behaviour (able to recognize situations and follow already defined procedures), which brings the operator to mistake due to a failure of expertise.

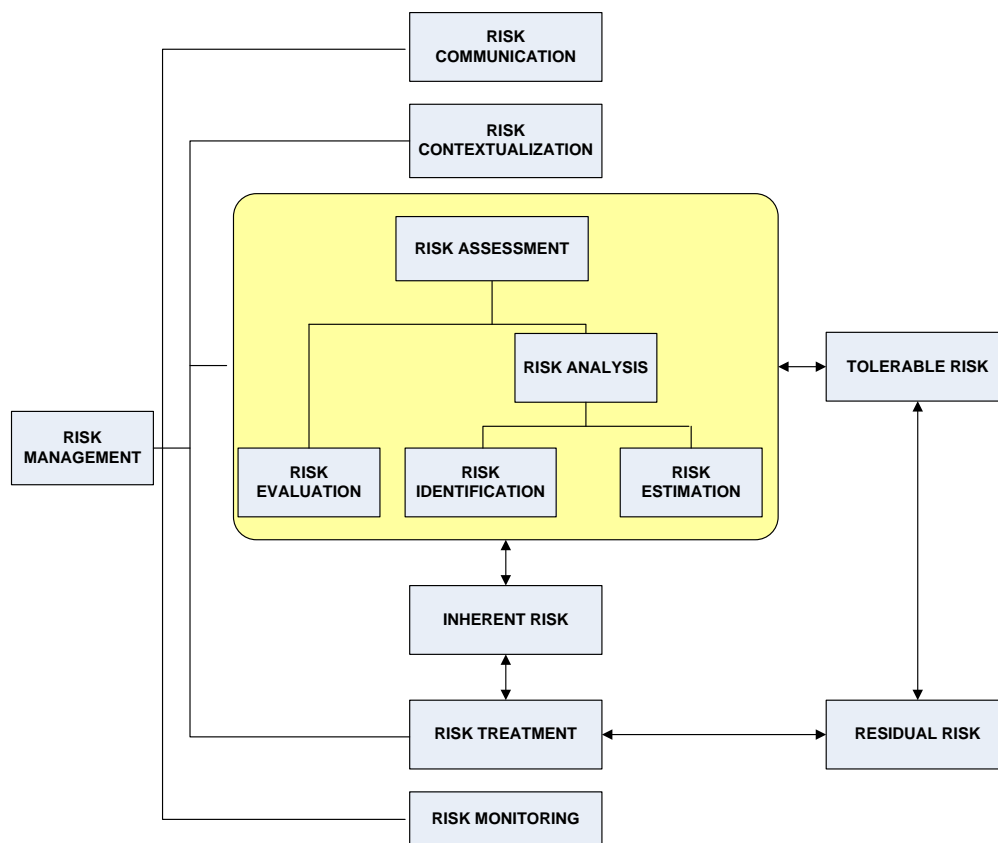


Figure 1. Risk management framework.

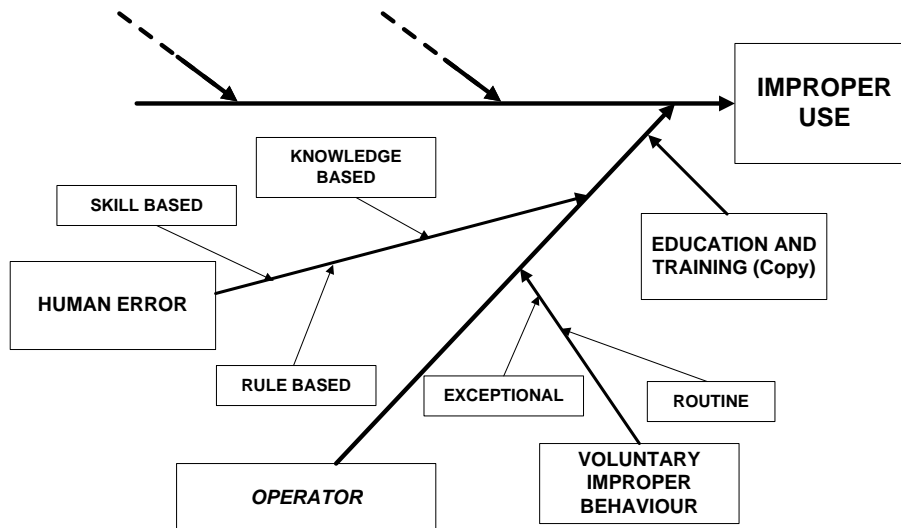


Figure 2. Excerpt of the application of the FBD method.

Results obtained showed that numerous factors can lead to an improper behaviour of the tractor's user, but most of them are related with the operator's training and education concerning safety and operative issues. In order to esteem the influence of such aspects on the level of safety of the operator, the ISSA (International Social Security Association) technique [ISSA, 2000] was used. This method allows the calculation of the risk of accident ( $R_a$ ), which is the result of the formula shown in the equation (1), where  $R_G$  represents the global risk and  $W$  represents the skills of operator in managing the risk:

$$R_A = R_G - W \times \frac{Mat}{30} \quad (1)$$

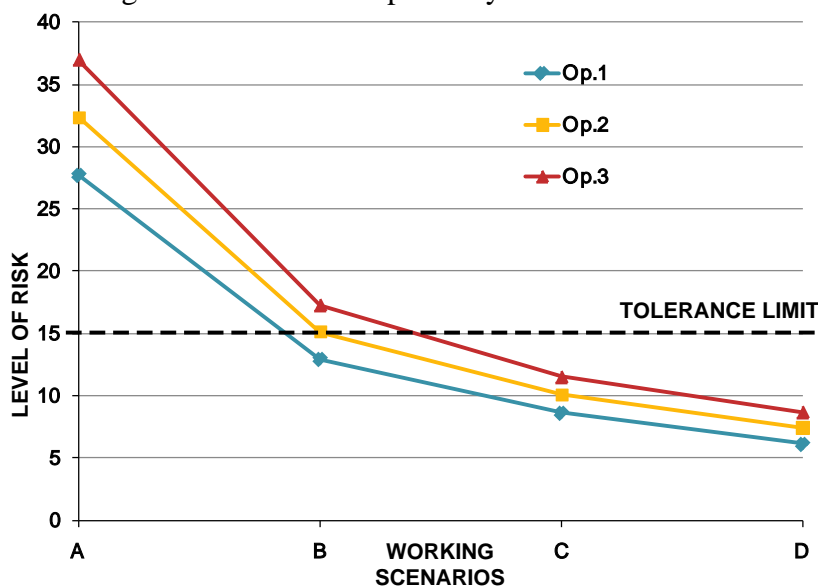
More in details, the operator skills can be estimated considering the following three aspects: the qualification degree of the operator, a coefficient which takes into account the physiological concerns, and the organization of working activities. Following these criteria, four different working situations (scenarios) were considered:

- A. tractor working in a vineyard (slope), with towed equipment and front side ROPS, which can be dismounted manually;
- B. tractor working in a vineyard (slope), with towed equipment and front side ROPS, which can be dismounted only using a specific tool;
- C. tractor working in a vineyard (slope), with towed equipment and rear side ROPS, which can be dismounted only using a specific tool;
- D. tractor working in a greenhouse (plain), with towed equipment and front side ROPS, which can be dismounted only using a specific tool.

For each one of them three different typologies of operator were taken into account:

1. skilled and expert user (Op.1);
2. skilled, but beginner (Op.2);
3. beginner, i.e. without experience (Op.3).

Main results of the analysis are shown in Figure 3, where the tolerance limit, i.e. the level of risk which can be considered acceptable, is represented by the dashed bold line: below this level, the user can manage the risk and most probably avoid the accident.



**Figure 3. Influence of operator's skills on the level of risk.**

The level of risk of skilled users, i.e. operators who received a specific training in using tractors and in managing occupational safety issues, resulted in being rather acceptable in most situations. The only situations whose risk was higher than the tolerance limit occurred in the case of non skilled users (scenario B), and non conformity of the machine (scenario A).

It has to be underlined that in many cases the operator voluntarily remove the ROPS when operating in narrow environments, such as greenhouses or vineyards; but quite often do not set it back when moving to different places. Thus, apart from novel design solutions which could be applied for the development of new machines, prevention measures for reducing the

risks connected with this kind of working activities concern mainly information and training measures for operators.

## **6. Conclusion**

The new Machinery Directive, as well as recent updates of Italian law on occupational safety, have a significant impact on agricultural and forestry activities: tractors' manufacturers and users have to consider numerous risks, which have been disregarded so far.

The approach developed for performing the risk assessment activities resulted in being a supportive framework for the analysis of these types of machines, allowing us to bring to light the importance of information, training and education of tractors' users.

At the same time, we have to underline that tractors (at least most of them) and a large number of self-propelled agricultural machinery can be considered as special vehicles from safety point of view, such as trucks, buses or forklift trucks, and indeed for this reason their users should need a specific licence or a specific training, as suggested also by art. 73, c.5 of the Italian Law about occupational safety. With this aim in mind, the present research work is currently in progress, focusing the attention on tools for assessing the human factor, with the goal of defining a set of criteria for the training of tractors' users.

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