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Information, Formation and Training for the Maintenance Operations: the Lesson Learned from Fatal Accidents

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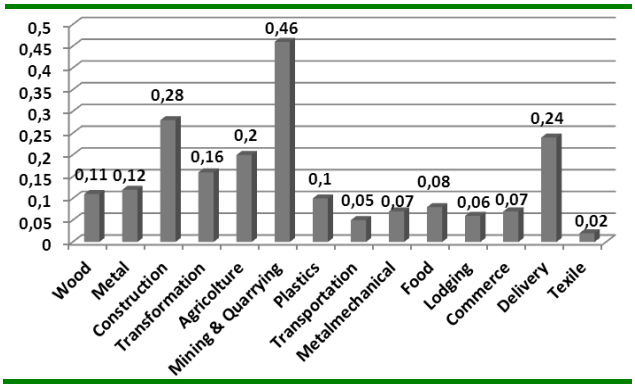
The list of possible machinery / equipment-related injuries is as long as it is worrying; they represent a non-negligible part of the total accidents in most industrial sectors, in terms of both numbers and severity, in normal conditions and during the maintenance operations (maintenance being the keeping of items or equipments in serviceable conditions to guarantee reliability and safety; it includes both corrective and preventive activities, and can be carried out in all sectors and workplaces).
Table 1 brings into evidence that these criticalities are quite common in the case of construction machineries / equipment.
Lack of maintenance or inadequate maintenance can lead to dangerous situations, accidents and health problems; but, at the same time, maintenance itself is a high-risk activity due to special hazards resulting from the particular nature of the work. Moreover, the workers involved are more likely than other employees directly exposed to the risks, since direct contact between the worker and the machinery to be maintained cannot be substantially reduced.
For this reason, the maintenance operations should be managed by properly formed and trained operators, to avoid incorrect actions that could generate unscheduled production stops or injuries.
On the basis of in-deep analyses on fatal accidents, carried out within Prosecutor investigations, the intermediate events chain and the root causes are here discussed, together with the possible prevention actions of both the direct consequences of incorrect operations, and the indirect consequences due to poor inspection and maintenance of earthmoving machines.

Table 1: A review of accident data referred to 10^3 workers (Camisassi et al., 2006).



In Italy, the fatal injuries in loading/haulage and material handling operations are related to the machinery, material and people transportation both in mining (20 ÷ 30 % of the total fatal injuries) and in road/railway constructions sector (25 ÷ 30 % of the total injuries); otherwise in the U.S. mining sector the fatal injuries are almost related to the handling material and powered haulage machineries in the range of 30 ÷ 35 %,

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while in road / railway constructions sector the 30 ÷ 35 % of the fatalities are connected to the pedestrians stuck-by vehicles and vehicle rollovers.

1. Maintenance and involved Occupational Safety and Health (S&H) criticalities

Maintenance is a generic term for variety of tasks in very different sectors and working environments, which includes activities such as inspection, testing, measurement, adjustment, replacement of parts, servicing, lubrication, cleaning, etc.
According to the European Standard EN 13306, maintenance concerns the "combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function".
The Maintenance operations are essential to ensure continuous productivity, to grant high quality products, and to keep company's competitiveness (Figure 1a): in general terms to keep machines and work environment safe and reliable for all the people involved. .As discussed in FACTS 27 (European Agency for Safety and Health at Work, 2002), "accidents and occupational diseases can give rise to heavy costs to companies. For small companies particularly, occupational accidents can have a major financial impact". Moreover, the Health and Safety Executive (HSE) lists: production disturbance costs (cost of recruitment and work reorganisation), health and rehabilitation costs, administrative and legal costs.
But, maintenance itself is a high-risk activity, and it has to be performed in a carefully pre-analyzed safe way, with the adoption of appropriate safety measures for the maintenance crew and other people present in the area: the available statistics (European Agency for Safety and Health at Work, 2010) indicate (Figure 1b) that: a) in several European countries approximately 10-15% of all fatal accidents can be related to the maintenance operations, b) occupational diseases and work-related health impairments (asbestosis, cancer, hearing problems and musculoskeletal disorders) are prevalent among workers involved in maintenance activities.

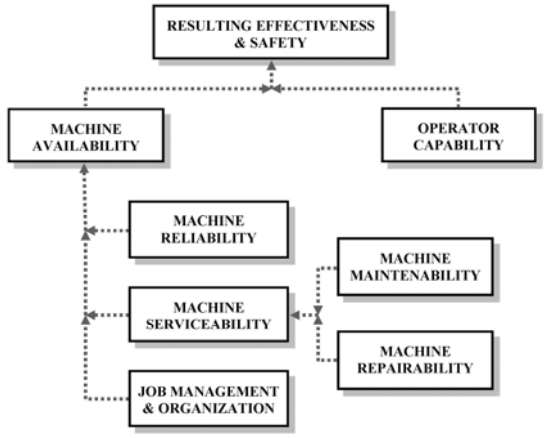

Figure 1a: parameters conditioning the job effectiveness and safety.

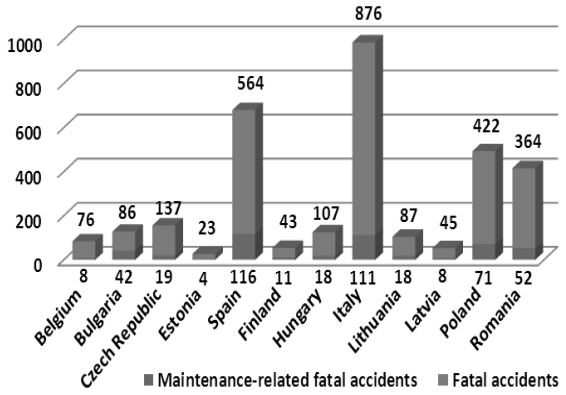

Figure 1b: number of fatal accidents related to maintenance operations in EU-countries (2006).

In addition to the risks associated with every working environment, maintenance operations can be needed in all sectors, workplaces and working environment, can require a wide range of different changing tasks, sometimes with staff from contractors, can impose time pressure, on-call work and irregular working hours, and can involve a number of specific risks, such as working alongside a running process and in close contact with machinery, unusual work and non-routine tasks performed in exceptional conditions (confined spaces([1]), access to unprotected parts, exposure to free energies and pollutants); finally, the subcontracting, a common situation for the maintenance operations, is an important aggravating factor in terms of safety and health.
The Modus Operandi involved during the maintenance / repairing operations is affected by the typology of maintenance that was adopted.

[1] It is not uncommon to record exposures e.g. to airborne particulates due to maintenances operations on the components and compartments of a machine impressively higher than the ones recorded for the same machine operators, even if the machine is used in dusty areas due to the amassed particles in the compartment.

It is generally possible to identify two different situations:

a. Activities that are expected to be carried out by official maintenance personnel (routinely, in the case of scheduled maintenance) or to correct unexpected failures; the machinery / equipment is tested after the intervention, and the results recorded;
b. Activities on charge of the machine operator: routine lubrication, cleaning and adjustments, and elementary problems correction.

Dramatic safety criticalities can arise if the boundary between the two situations is not clearly defined or understood, or disregarded under time-pressure conditions: information, formation and training should be the first step to identify the topics of "how to correctly do" and "what avoid to do" ([2]).

2. The Occupational S&H in the European regulations

2.1 The European Directives of basic relevance

The Table 2 summarizes the essential steps and results of the European approach.

Table 2: European approach to the Occupational Safety and Health.

- ✓ Treaty of Rome (1957): among others, also a common commitment was introduced to improve the Safety and Health of workers at the workplaces (art.118a).
- ✓ Single European Act (1985), modifying the art. 100 and 118 of the treaty of Rome: the safety was recognized as a shard principle for the approximation of the laws of the member States relating to machinery.

SOCIAL DIRECTIVES	ECONOMIC DIRECTIVES
❑ Directive 89/391/EEC of 12th June 1989, *on the introduction of measures to encourage improvements in the Safety and Health of workers at work*	❑ Directive 89/392/EEC of 14th June 1989, on the approximation of the laws of the Member States relating to machinery *[replaced by 98/37/EC and now by 2006/42/EC]*
❑ Directive 1999/92/EC of 16th December 1999, *on minimum requirements for improving the Safety and Health protection of workers potentially at risk from explosive atmospheres* (15th Directive within the meaning of Art. 16(1) of Directive 89/391/EEC)	❑ Directive 94/9/EC of 23rd March 1994 (updated), on the approximation of the laws of the Member States concerning equipments and protective systems intended for use in potentially explosive atmospheres

2.2 Machinery / equipment maintenance, and operators and maintenance personnel information, formation and training

The directives apply to maintenance activities, first of all the Council "Framework" Directive 89/391/EEC, the obligation for the employers to carry out an exhaustive Risk Assessment and Management, and to provide safe and reliable machineries and equipments.

Moreover, as a general approach, in the European Directives, the maintenance workers were identified as "workers who may be at increased risk", so that the need to conduct a separate Risk Assessment and Management for the maintenance activities becomes more evident and necessary.

For these reasons, on the basis of the "Framework Directive" a series of Individual Directives were adopted for carrying out maintenance in a safe way; many of them include specific provisions regarding maintenance activities and special safety requirements for maintenance (traceable in "Summaries of EU legislation" website).

With relevance to the machineries and equipments ([3]), and to their maintenance, it should be noted that in its preamble the 2006/42/EC Directive states that the social cost of the large number of accidents caused directly by the use of machinery can be reduced by inherently safe design and construction of machinery and by proper installation and maintenance.

It is also underlined that the machinery manufactured in conformity with a harmonised standard published in the Official Journal of the European Union shall be presumed to comply with the essential health and safety requirements covered by such a harmonised standard. ([4])

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[2] Taken into account the number and severity of the accidents involving machineries for lifting, loading and haulage in Italy, the Permanent Conference of State and Regions defined the course program for a special qualification and license of the operators. The attention is focused on the correct use of the machinery / equipment, but the official program does not cover the elementary maintenance, and the failure management.

[3] Even if formally defined in different ways, obviously the basic concept of a safe approach covers machines, equipments, fittings, tools, etc

[4] From the Guide to application of the Machinery Directive 2006/42/EC "a harmonized standard provides an indication of the state of the art at the time it was adopted. In other words, the harmonized standard indicates the level of safety which can be expected of a given type of product at that time. A machinery manufacturer who chooses to apply other

With special reference to the workers information, formation and training, in the 89/391/EEC Directive the informing, consultation, balanced participation and training of workers and their representatives are considered, ensuring that each worker receives an adequate (i.e. derived from a Risk Assessment special for the situation) Safety and Health training, consisting in specific instructions to the workstation or job, in every occurrence of job changing and in the event of the introduction of new/modified equipments. An obvious, but sometimes neglected, concept is that the una-tantum operations should be object of careful preliminary Risk Assessment / Management.
Moreover, the Annex I to 2006/42/EC Directive includes specific provisions for the users safety in terms of information, warnings and instructions; in particular, in accordance with the machinery "Contents of instructions", the formation and training of the workers should be provided also for the adjustment and maintenance operations.

2.3 Machinery / equipment inspection and efficiency tests logbook, and maintenance records

Asides from the official regulations in terms of logbooks for some machinery / equipment and systems typologies (in Italy it is mandatory for lifting equipment, cranes, telescopic forklifts, powered scaffoldings and pressure equipment) a record of the maintenance, inspection and test actions can be useful both for efficiency (Bonansea et al., 1988) and Occupational S&H reasons.
In particular, if the modern quality approach to the Occupational S&H problems is adopted (the art. 30 of the Italian law regulating the Occupational S&H (Decreto Legislativo 81, 2008) introduces this concept) in coherence with the OHSAS 18000 recognized international standards (OHSAS 18001:2007 and 18002:2008), a formalized logbook of maintenance, inspection and test actions becomes an implicit condition within the structure of the Hazard Identification and the Risk Assessment and Management activities.
During the Hazard Identification in fact, information should be considered on the facilities, processes and activities including the equipments specifications. Following to the completion of the Risk Assessment, and taken into account the controls measures already existing, the organization is in condition to decide whether such control measures are sufficient or further improvements are necessary according to the hierarchy of controls as suggested in the aforesaid OHSAS 18001:2007; the results of the process shall be registered.
Similarly, the organization should adopt suitable logbooks for machineries, equipments and plants ([5]), including basic data, manufacturer's instructions, and information on the inspection, maintenance and safety checks actions and results along the whole life in service, so that an exhaustive record can be available at any moment. Clear definitions of the people involved (maintenance personnel, machine operators, supervisors of the process, etc...) should be included.
Only such an approach can avert "imaginative" modifications, interventions aimed to restore the productive capability disregarding the safety conditions of the final result, and lay at the base of an effective information, formation and training of all the people involved, so that no safety flaw lays uncorrected, or misunderstandings arise.

3. Consequences of poor information, formation and training in maintenance

An original computer assisted technique for an in-deep analysis of work related accidents, not affected by the common problems of incompleteness and subjectivity, was recently developed (Demichela et al., 2011). Based on an evolution of the Cause-Consequence and Fault Tree Analysis techniques, the new approach, useful to focus step by step the intermediate and root causes of an accident, and to verify the expectable effectiveness of preventive measures, is here applied to two real cases (Table 3) carried out within Prosecutor investigations (loader operator struck by moving equipment during a maintenance operation / dump truck fell into a water filled pit).
The analysis put in evidence the strict causal connection between poor information, formation and training in maintenance, and dramatic consequences, both direct on untrained workers taking care of the maintenance operations, and indirect on operators of incorrectly inspected and maintained machines.

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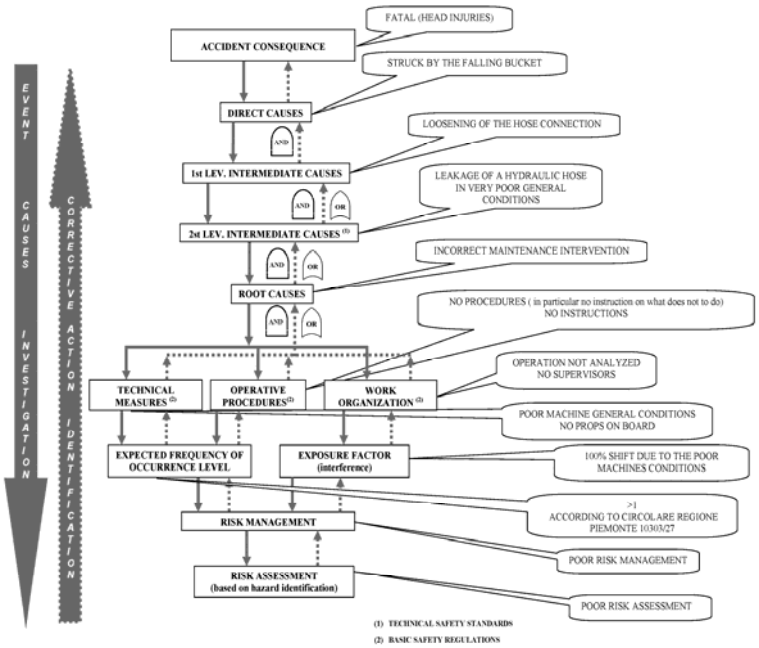
technical specifications must be able to demonstrate that his alternative solution is in conformity with the EHSRs of the Machinery Directive and provides a level of safety that is at least equivalent to that afforded by application of the specifications of the harmonized standard – see §161 and §162: comments on General Principle 3 of Annex I".

[5] Machineries, equipments and plants should be considered as direct Occupational S&H criticalities: an extended research work (Camisassi et al., 2004) led to the issuing of a local regulation Circolare Regione Piemonte 10303/27.02.

Table 3: The new approach tested on two real fatalities related to the maintenance operations

the machine involved into the event

the poor condition of the broken hose

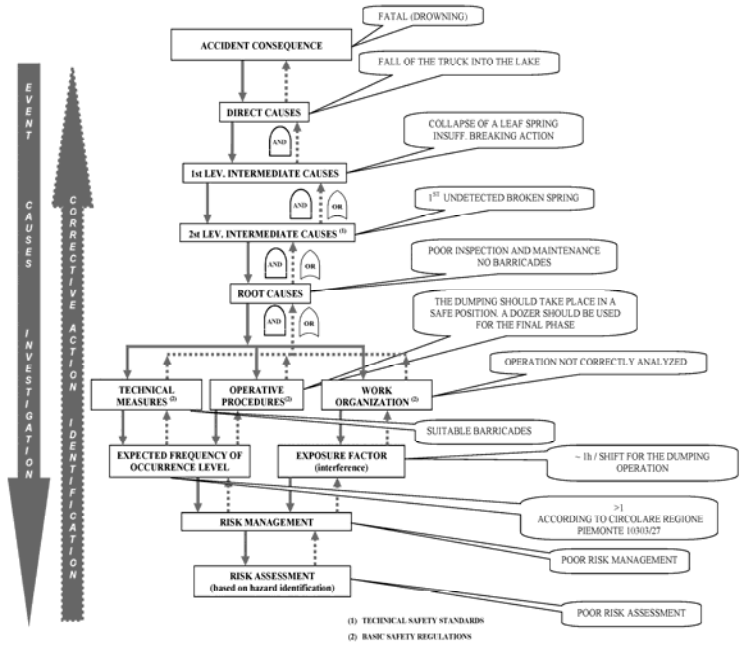


analysis of the accident

A hose of the hydraulic circuit feeding the bucket jacks started leaking. The operator tried to intervene and loosened the connection without preliminarily securing the bucket in the higher position. The bucket fell and struck the operator. No supervisor was present, no machine instructions on board and the prop provided by the manufacturer had been removed in the past. The victim worked under temporary contract.

the recovery operations

the couple of collapsed leaf springs



analysis of the accident

One of the rear right axle leaf springs got broken in the past, and the problem was not detected. The accident was caused by the sudden collapse of the 2nd spring in the maximum load condition during the dumping phase. The balance was then compromised and the breaking action not sufficient, due to the worn treads of the tyres of the 2nd axle. No barricades were installed in the dumping area.

4. Conclusion

As discussed, a correct maintenance is of paramount importance for the Occupational Safety and Health, both with regards to the maintenance personnel and to the operators. In the authors opinion, the only way to prevent accidents with dramatic consequences is to carry out a careful Risk Assessment and Management, aimed to grant a safe running of the machines, equipments and plants special for these operations, and the necessary inspections, maintenance and tests, upon which to base the information, formation and training of the workers involved, no matter how occasional the interventions can be.

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