Load and hauling machinery: an evaluation of the hazard involved as a basis for an effective risk evaluation

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Loading and haulage machinery: an evaluation of the hazard involved as a basis for an effective risk evaluation

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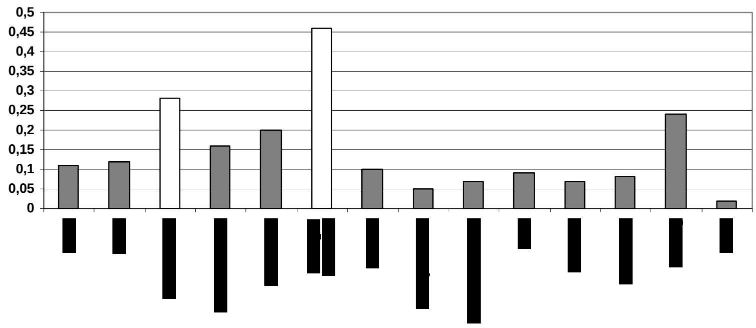
ABSTRACT: There is worldwide statistical evidence that a quite large number of work associated accidents causing fatal or serious injuries can be correlated to the use of machines, involving the machine operators or other workers present in the proximity. The situation appears to be particularly critical where the construction and extractive activities are considered (both opencast and in underground), mainly due to the special operating and environmental conditions and to the impressive specific power ratio (in terms of horsepower/man) reached by the earthmoving machines here employed.
A research work is since some years being carried on on the risk analysis and management techniques suitable for the aforesaid operations, and the resulting well tested technique was adopted as a guideline by some official institutions. The paper deals with a further improvement of the technique, made possible by an extensive field research and direct data collection.
The target being to pinpoint the criticality of the different categories of machines, in order to provide the risk analysts with reliable info upon which to develop an effective risk analysis, the research work was carried out according a series of basic steps, as discussed in the paper.
The final research work result is a reliable technique suitable to "weight" the criticality of the different families of machines in their practical use. The achieved results are discussed with reference to the machines typologies more widely used in the earthmoving operations both in construction and extractive operations.

1 INTRODUCTION

It is commonly recognized that the mining and construction operations are quite concerning where the safety and health of workers are considered, in terms of both number and severity of accidents.
Moreover, where the fatal or seriously injuring accidents at mining/quarrying activities (metal & non metal, coal mines here not considered due to the quite different techniques-technologies involved) and construction sites where important earthmoving operations are carried out (typically road and railway construction sites) are analyzed on the basis of statistical data, it can be observed that the loading / haulage / material handling operations appear to be the most important accident causes.
Such a statement can be accepted on a worldwide base, as confirmed e.g. by the comparison of the data drawn both from the Italian Workers' Compensation Authority (INAIL website) and the U.S. Department of Labor (Occupational Safety & Health Administration OSHA and Mine Safety and Health Administration MSHA DOL Agencies websites) - see Table 1.
As an obvious consequence, and to copy with the Italian law requirements (enforcements of the European Directives on the introduction of measures to encourage improvements in the safety and health of workers at work) to get an effective risk prevention result a very careful risk analysis should be applied to the aforesaid operations.

Table 1. A review of accident statistical data.

a - Fatalities vs Industrial activity (Italy - ref 10^3 workers)



b - fatal injuries in loading/haulage & material handling operations

Italy mining ([1,2])	Italy road / railway constructions ([1,2])	USA mining ([3])	USA road / railway constructions ([4])
20 ÷ %	25 ÷ 30 %	60 ÷ 35 %	25 ÷ 30 %

([1]) Data available ref (2000 ÷ 2004) - the '04 N.D. causes amount to 40%;
([2]) Machinery, material and people transportation;
([3]) Handling Material / Powered Haulage ± Machinery;
([4]) Pedestrian Workers Struck-by Work Zone Construction Vehicles & Work Zone Vehicle Operator and Occupant Events (e.g. Rollovers).

2 THE RISK ANALYSIS AND MANAGEMENT BASICS

The main results achieved by the authors in order to provide a well tested guideline for an effective approach to the risk analysis and management in mining and other earthmoving operations were presented in the 1996 - S.H.C.M.O.E.I -Safety and Health Commission for the Mining and Other Extractive Industries- Workshop on Risk Assessment (Faina et al. 1996), and are published in the Official Documents Gazette of Lombardia Region (BURL 2002, n.8, Annex 2 2002) - see Table 2 where the basics of the approach are summarized.

The safety of machines (the load/haulage and material handling machines included) was specially analyzed according to the general approach principia as previously discussed, and the achieved results are presented in Camisassi et al. (2004) and published in 2004 in the Official web site of the Piemonte Region Public Health Dept (doc. 10303/27.02 2003).

The described basic approach to the safety characteristics and safe use of the machines as officially approved by the Piemonte Region Public Health Dept can be summarized as in the following:

A - as discussed in Table 2, the approach is based on the statement that minimum probability of occurrence of damageous events corresponds to a situation coherent with the progress of the safety technical standards. Where the machines are considered, this means that:
   - A.1. the Essential Safety Requirements (ESR) as stated by the 98/37/EC Directive should in any case be fulfilled;
   - A.2. the C type standards special requirements -where available- should be respected.

B - the statement of cause A being quite obvious where the machines produced after the National enforcement of the 98/37/EC Directive, it must nevertheless be underlined that the same ESR and C type standards should be used as a technical reference -*special checklists, directly drawn from the aforesaid documents proved to be quite effective and user friendly*- for an effective risk analysis of older machines: in the case of incomplete accomplishment, appropriate risk management is necessary, in terms of technical improvements, where possible, or of different solutions, such as limitation of use to safe situations. Moreover, in no case the use of machines not accomplishing to the Italian Law statements can be accepted (e.g. containing parts fitted with asbestos dampeners - see. L.257/92).

C - the correct use of the machine should furthermore be carefully investigated in terms of risk analysis, to avoid situations where a safe machine involves accident problems due to inadequate size, weight, ecc., taken into account the Manufacturer's recommendations and info on foreseeable improper use. The results of such an analysis, together with the maintenance requirements, should be included into the workers training.

3 THE RESEARCH WORK HERE DISCUSSED AND THE ACHIEVED RESULTS

In closer detail, asides from the proposed loading and haulage machines general risk analysis and management approach, some further info appeared to be necessary in order to define a hierarchy of involved risk associated to the different machines used in the loading, haulage and earthmoving operations, basically to the track or rubber tyred free steering loaders, hydraulic excavators, off-highway construction and mining trucks, front and angle blade dozers, scrapers and graders.
At the purpose a special research work was organized, as follows:
the number of accidents associated to the use of the aforesaid machines was evaluated -Table 3.1. together with the most common causes of accidents at mines and construction sites causing injuries to the operator or other workers, which can be ascribed to:

- ⇨ *poor safety conditions: old machines, leaking of the up to date safety devices, or incorrectly maintained;*
- ⇨ *artistically modified machines, sometimes to fulfill tasks different from the original ones;*
- ⇨ *incorrect selection of the machine, even if accomplishing the safety requirements;*
- ⇨ *leak of respect of the safe use procedures.*

a criticality factor was then identified, to consider (Tab. 3.2):

- ⇨ *the number of fatalities associated to the use of the different machine type;*
- ⇨ *the number of machines (most common types: loaders, excavators and trucks) at some sites;*
- ⇨ *the use rate as evaluated from the maintenance/worked hours records.*

4 CONCLUSIONS

The importance of a careful risk analysis and management of the loading / haulage and material handling operations was confirmed by means of an extended analysis of statistical data.
These operations in fact involve a large number fatal or seriously injuring accidents both in mining and construction operations where important earthmoving is required.
The research work here discussed made available an effective technique -based of direct field recorded data- which can be of help where the target is to identify the most critical machine type (the first to be considered in the risk management time and money consuming phase, since in a number of cased this implies a different work organization to correctly manage the interferenced, or, in case of older machines, even a substitution with new and safer ones).
The approach leads to the numerical evaluation of the criticality factor KR, whose meaning can be summarized as follows:

> for a stated number of accidents and an involved type of machine,
> – *the smaller the number of the used machines of the considered type;*
> – *the smaller the percentage of work shift during which the machines are used*
> the higher the criticality factor KR

It must be strongly underlined that the KR factor can be used to analyze the situation with reference to the machines, and it is common knowledge that an old, underused machine which can't be considered efficient for the main production is often applied to special operations even if not suitable, and, as a consequence, particularly risky. The risk involved by the efficient and properly maintained machines has been discussed in Table 2, where the *contact factor* meaning was introduced.

Table 2. Guidelines for an effective risk analysis and management approach as approved by S.H.C.M.O.E.I.

A - from the usual definition:

$$RISK = \text{predictable damage due to the event } M \times \text{probability of occurrence of the event } F$$

since in the industrial activities not covered by the 2003/105/EC directive, such as in our case, we can write:

$$M = pd \cdot fc$$

where:

pd = severity of the possible damage (death, injuries and health impairments, etc..)

fc = possibility of interference (or contact factor) which is function of the percentile exposure time to operations or situations potentially hazardous compared to the working cycle

then:

$$RISK = pd \cdot fc \cdot P$$

B - a numerical risk evaluation unbiased by subjective estimation can then be reached, where:

- the damage severity pd is expressed in terms of lost working days according to UNI 7249/1995 standard (workers accident statistics - frequency/severity coefficients) and D.P.R.1124/65 (dispositions for worker's liability insurance);
- the interference fc can be estimated in terms of % of the work shift involving the exposure to each hazard
- the probability of occurrence of the event P, i.e. the possibility of deviation from the correct work organization/development, can be numerically evaluated in a simplified way (according to the UE suggested approach see Doc. 5196 1994):
  - ✓ the minimum probability of occurrence of damageous events obviously corresponding to a situation coherent with the progress of the safety technical standards, a simplified and effective approach to the evaluation of P can be based on the use of the *relative probability of occurrence*, written as:

$$PR = \frac{\text{Probability of occurrence of damageous events (situation under examination)}}{\text{Minimum Probability of occurrence (according to up to date standards)}}$$

1 situation according to the technical progress
≤ 1 situation not according to the technical progress

  - ✓ the approach provides an adequate evaluation of the possible severity of event's consequences, since in a situation accomplishing to the regulatory requirements there won't be any worsening in consequences due to other flaws (for example in terms of communication, organization of first aid, etc..).

C - to identify the risk factors the following approach is recommended:

⇒ *preliminary general analysis (e.g. the site characteristics)*

⇒ *safety analysis of every working activity (for example through the use of a Job Safety Analysis);*

⇒ *identification and management of interferences (Organization (e.g. PERT) & Functional Spaces An.)*

⇒ *failure analysis by means of* ***Hazard Evaluation Techniques***

The minimization of the not avoidable risks can be achieved directly during each analysis stage (proactive prevention), as exemplified with reference to a J.S.A

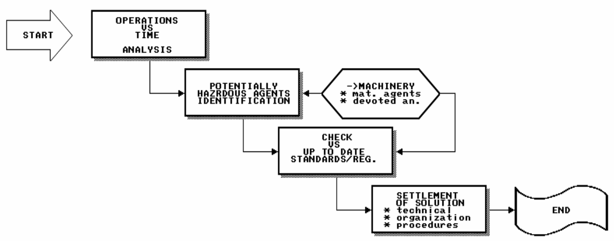
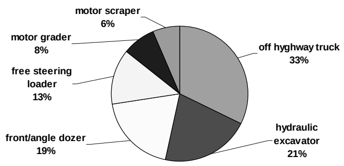
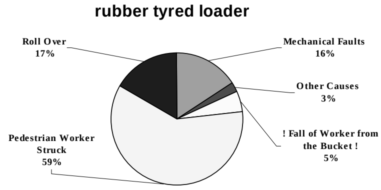


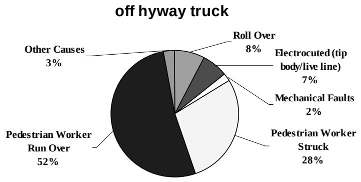
Table 3. The research results.

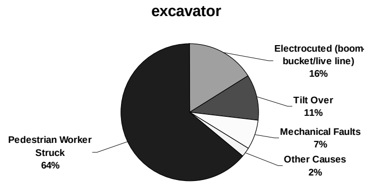
Tab.3.1. - fatalities associated to loading/haulage - material handling machines (mines & earthmoving operations)



OSHA / MSHA data - *no data of such a detail are available in the Italian data bases*



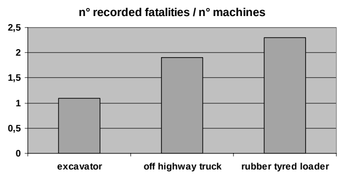


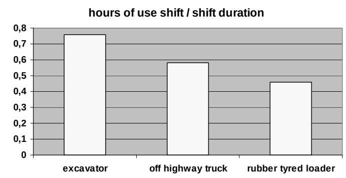


Tab.3.2 - criticality factor

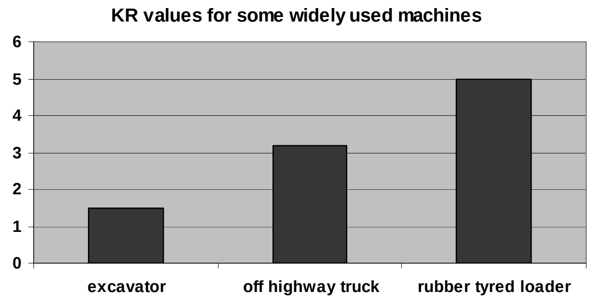
Definition: ***KP = [n° recorded fatalities / n° machines] / [hours of use shift / shift duration]***

esperimental data





final result



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