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RISK AWARENESS VERSUS RISK ASSESSMENT IN MANUFACTURING: A FIELD STUDY.

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Risk assessment in manufacturing work environments gives a relevant contribution to health and safety management for the operators: hazards are identified, and the associated risks are quantified in order to promote the risk mitigation and to improve the safety level for all the workers involved. In this paper the relation between the risk assessment performed by Safety managers and workers' risk awareness is investigated using as case study a manufacturing plant (heavy vehicles) in Northern Italy.
Risks are assessed with a set of widely used procedures and methods that return a level of risk related to each workplace. According to the most recent Italian regulation on safety at works (D.Lgs. 81/08) each worker has to be informed and trained about all risks he would be exposed to during her/his working activity. Operators are the final stakeholders of this process that started with a risk assessment performed by experts and ended with a transmission of information involving safety, personal health and working behaviour.
To compare risk assessment and risk awareness, a field study was performed with more than 50 workers surveyed on their personal awareness of level of risk associated to their working task. The comparison highlighted significant miss-matches that are here discussed. To solve this miss-match a review of safety information methods and safety training for workers was identified as countermeasure.

Keywords: Risk-awareness, Risk-assessment, Hazards, Safety Climate, Human Factor, Accident Prevention.

1. Introduction

Occupational accidents and occupational diseases are critical problems affecting industry sector today. In italian industry, for the first 9 months of 2018, they accounted for more than 370000 injuries, 491 deaths and 34700 occupational diseases according to the INAIL latest data. This amount of events has a strong economic and social impact (Battaglia et al, 2014) and reducing the incidence of them is one of the primary concerns of any National Safety Policies.
To face of this problem, according to EU Directive on work safety, Italy emitted two major laws: in 1994 the Dlgs 626 that introduced the using of risk analysis principles for the working condition and in 2008 with Dlgs 81/08 that overcame previous national regulations and extended the using of risk analysis to all possible hazards linked with any working activity. Since 1994 a reduction trend of occupational accidents was reported by INAIL but addressing it completely to the regulations effectiveness was not possible because multifactorial elements from macro-economic to social changes had an influence on it (Comberti et al., 2017). Dlgs 81/08 disciplined the safety management of companies with several mandatories rules that are mostly related to the following steps:

- Identification of all possible hazards related to all kind of working activities;
- Risks assessment of all working activities and risks reduction when risks were classified as not acceptable.
- Information and training for all workers with reference to risks assessment results.

First two steps of this process are managed by Safety experts and their results are transferred to workers into the third step.
As a practical consequence of this approach, workers are informed and trained about safety procedures and provided with personal protective equipment (PPE) where necessary. However, training and PPE are only effective when workers comply with the trained procedures and use properly the PPE (Diaz et al., 2000). Several works analysed the factors influencing the effectiveness of safety measures in companies and they leaded to different conclusions.

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The concept of "Safety climate", as sum of employees' shared perceptions of the policies, procedures, and practices relating to safety in their work environment, and the concept of "Safety Culture", in her different definitions (He et al., 2012) were identified as crucial to gain good safety performances (Huang et al., 2006). The constructs used to assess them have varied from study to study, (Liu et al., 2015) depending on the field of analysis (Barbaranelli et al., 2015) and a common view was difficult to fix due to the range of theoretical debates that abounds (Borys d., 2009).

Far away to give a contribution to the debate around the Safety Culture and Safety Climate role, this paper gives a contribution to the analysis of the effectiveness of safety measures in companies. That considering the correspondences between safety information as assessed by Safety managers and safety knowledge and behaviour as aware by workers.

Safety measures, including information, PPE and training are defined by Safety managers with a risk analysis process. The transfer of this set of knowledge to workers can be viewed as a communication problem. The effectiveness of this process is strongly influenced by a lot of factors and it is dependent on the validity of a common code of communication (Eco U., 1975).

The analysis of this process can be summarised by two fundamental questions:

1. the set of safety-knowledge is correctly transferred from the source (Safety Management) to the addresses (workers) without lack of information or any misunderstandings?
2. Workers use properly the set of information acquired during the information and training-steps?

With reference to the first question, the success of this communication is strongly dependant to the level of workers perception on the management commitment to safety. In other words if the company's incentive system for productivity overshadows the safety program, worker may sacrifice safety compliance to achieve greater production (Clarke S., 2006).

Another factor influencing the loss of significance during the information and training process was identified in the gap between risk perception of managers compared to workers risk perception (Arboleda et al., 2003). Second question is more related to the concept of Safety performance and the way to measure it.

Occupational accidents analysis is a common way to assess the safety performance (Comberti et al., 2015 and 2018,a) and to identify the lacks in the safety-training program (Murè et al., 2017, Leva et al., 2017).

This approach is not applicable to all those situations with very low accidents rate (Baldissone et al., 2015). In this case the accident pre-cursors analysis represents a promising toll to measure safety performances (Murè et al., 2015) and safety measures effectiveness.

Workers trained and equipped to work in safe conditions not always follow safety rules (Leva et al., 2018).

Companies use various reward systems and negative reinforcement to encourage workers to comply to safety rules but this system has not appreciable results (Falck et al., 2014). Several factors may affect workers compliance behaviour and related performances (Comberti et al., 2018,b).

Some authors (Baldissone et al., 2018) identified the conflict between workers and managers as a common case of low compliance, others highlighted the role of personal experience (Slimak et al., 2006) where workers who have personally experienced the consequences of an industrial accident should be more likely to perceive a task as risky and comply with safe behaviour. More in general the compliance to safety rules appears to be related to the level of Safety Climate (Christian et al., 2009).

This paper outlines the results of a field study performed into an automotive plant with the aim of analysing the relationship between risk assessed by Safety experts and risk aware by workers. Section 2 of this paper describes the methodology used to carry on this study and section 3 provides some results. Conclusions discuss the results and ended the paper.

2. Materials and methods

This work was carried on into an automotive assembly-plant where relevant effort in term of safety improvements have been made. The plant was organised in a series of assembly lines composed by a sequence of working-places where a shell is moved automatically from a workstation to the next following a certain rate called takt-time. In all working-places a task is performed on the shell according to a specific well defined procedure. Each task, according to the kind of operations and tolls used, exposes worker to different risks: from ergonomic to operational.

Health and Safety (H&S) managers performed a detailed risk analysis for all working stations according to Italian Safety Regulations requirements. Results of this analysis were used to define the work-organisation, to identify the PPE and the Safety rules. This set of knowledge and tools was transferred with a training and informative process to workers. To investigate the relationship between risk assessed and how risk was aware by workers it was selected an assembly line of 26 working stations involving 50 workers. The methodology adopted investigated two fields with a different nature: the risk assessment performed by H&S experts and the risk as it was aware by workers. To make possible a comparison within these fields it was necessary to develop a common scale of evaluation (Gerbec et al, 2017). As a consequence of this the project was developed as it follows:

- Analysis of Risk assessment results and re-classification of Risk according to a categorical scale with 3 level of degree (Low, Medium, High).
- Assessment of perceived risk by workers with a survey consisting in a set of unanimous questions related to risk perception and safety rules evaluation.
  Workers were asked to answer to each question giving an evaluation in a categorical scale with 3 level of degree (Low, Medium, High).
- Analysis of safety performance expressed in term of full, partial and absence of compliance to safety rules with a specific focus to PPE proper using.
- Results comparison.

2.1 Risk assessment analysis.

This step was developed with a participatory approach (Comberti et al., 2019) that involved H&S and Working Organisation plant experts. Risk was assessed by H&S managers identifying all hazards of each working stations and providing for each of them a risk according to the classic expression:

$$R = PxD \quad (1)$$

where:

- R is risk;
- P represents the probability;
- D represents the damage.

P and D values were calculated using a numerical scale from 1 to 4. As a result of this approach each working station was characterised by a number of risks with a value included between 1 and 16. To rank the working stations on the basis of the risk, a global risk "R_g" was introduced as sum of all risks assessed in the single working station according to eq. 1. Figure 1 summarises R_g values for the assembly line selected as case study.

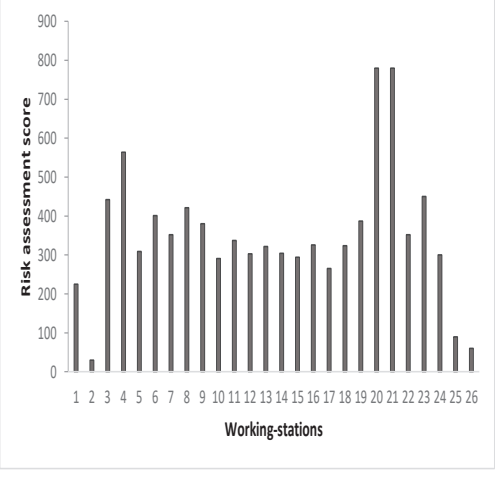

Fig. 1. R_g assessment of working-stations.

Figure 1 highlights how R_g can differ passing from a working-station to another one. Even if the working stations are components of the same assembly line the R_g has a range of variation from a minimum value of 30, of working station 2, to a maximum of 800 for working-stations 20 and 21. To allow the comparison between R_g assessed R_g as it was aware by workers R_g values were re-calibrated into a 3 level scale where:

- R_g assessed from 0 to 200 was scaled to 1;
- R_g from 200 to 400 was scaled to 2;
- R_g major than 400 was scaled as 3

To support this scaling action a task analysis (Jung et al., 2001) and a visual inspection of each working-station was performed. Information acquired allowed a better understandings of the risk assessment of the whole assembly line.

2.2 Perceived risk assessment.

The data were obtained through questionnaire distributed to the workers. Respondents answered voluntarily after being briefed by the researcher on the objectives and the items in the questionnaire. Questionnaires were compiled in an anonymous way as requested by labour organisation and to let the workers free of express their own personal feeling without the risk of being badly judged by their supervisor in case of criticism to the safety policies. Questionnaire was composed by a list of 5 questions as summarized in Table 1.

Table 1. List of questions for the interview

Question	Topic
1	Which is the level of risk of your working station?
2	Is it easy to identify the hazards you're exposed during the working activity?
3	Do you report to your supervisor any safety problems?
4	PPE provided for your working station are useful?
5	Safety panel and safety visual warnings are useful during the working activity?

Workers were asked to answer to each question with a scale from 1 to 3 where:

1- Low;
2- Medium;
3- High.

Questions number 1 and 2 were more related to risk awareness, question number 3 was related to the level of involvement of workers into safety process. Question number 4 was used to analyse the eventual difference between the knowledge and the behaviour. The last question was included to investigate the workers perception of the system of safety panels and warnings located along the assembly line.

2.3 Safety performance analysis.

Safety performance are generally measured, at plant scale, in term of number of occupational accidents recorded and number of light medical treatment. At assembly-line scale a good alternative is represented by unsafe act monitoring with particular emphasis to PPE using (Comberti et al., 2015b). With reference to the level of risk assessed all working-stations required one or more PPE. The proper using of the prescribed PPE was monitored during a period of two weeks.

2.4 Comparison of the Results

Results obtained from the risk assessment re-classification have been compared directly to result of question number 1. The using of a common scale of evaluation allowed a direct comparison between the distribution of the results. Any difference identified can be representative of a misalignment between risk as was assessed by H&S service and as was perceived by workers. Other answers were used as feedback on the general level of compliance to safety rules and safety culture promotion.

3. Results

Results obtained from the scaling of the R_g values (Figure 1) were summarised in Figure 2. R_g of the working-station was scaled into 3 classes from low risk to high risk. The terms used to describe the levels of the used scale have a relative value. All risks assessed by H&S service were, with the set of PPE and safety rules, considered as acceptable. Figure 2 highlights how the R_g distribution was strongly polarized in "medium" class with the majority of working station included. In fact the assembly line was characterised by 4 working station with a value ranked as "low risk", 18 working station ranked as "medium risk" and 3 working station ranked as "high risk".

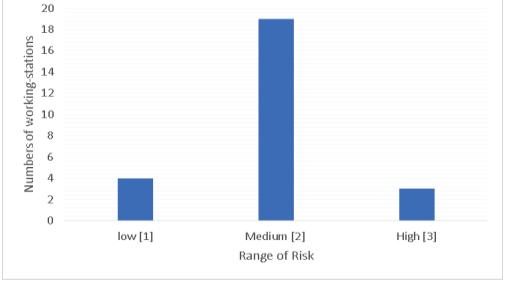

Fig. 2. Rg of working-stations scale

R_g values provided a quantification of risk which each worker was exposed during his own working activity, depending to the working station. This information was transferred to the worker by the H&S service with a specified set of PPE and safety procedure. To check if this process was correct the analysis of the distribution of the perceived risk by workers was done analysing the distribution of answers to question 1 of the questionnaire (Table 1). Figure 3 summarises this result ant it shows how the distribution of worker's perception of risk associated to working-station was strongly focused on the "low" category.

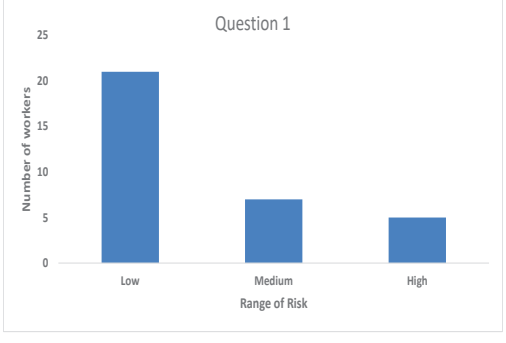

Fig. 3. Risk related to working-station as aware by workers.

Results related to the answers distribution of question 2 to 5 were summarised in the Figures from 4 to 7.

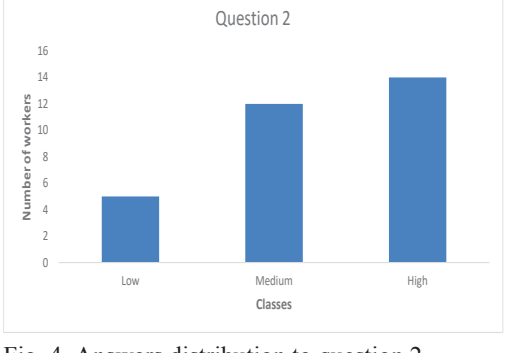

Fig. 4. Answers distribution to question 2.

In particular Figure 4 highlights how workers find easy to identify hazards in their working station during the working activity. This result seems to be in accordance to results of question number 5 (Figure 5) where it was asked if the safety panels and safety warnings allocated into the working stations by H&S service to prevent injuries were perceived as useful by workers.

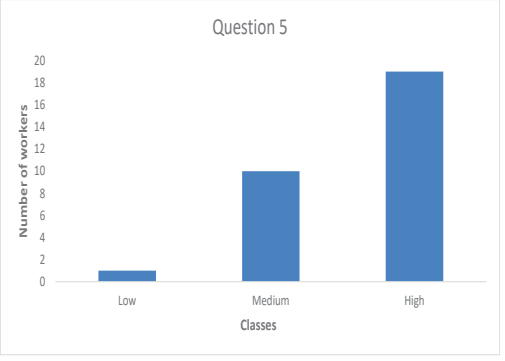

Fig. 5. Answers distribution to question 5

Workers opinion about the PPE usefulness was investigated by question number 4 of table 1. Answers were summarised in Figure 6.

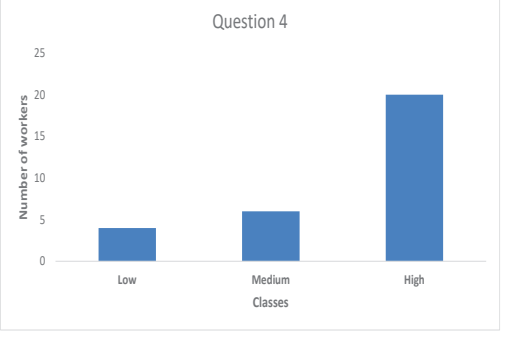

Fig. 6. Answers distribution to question 4.

Figure 6 highlights how workers considered very useful the PPE provided by H&S service because only 3 workers assigned them a low value. Last question analysed was question 3. Figure 7 summarises this result.

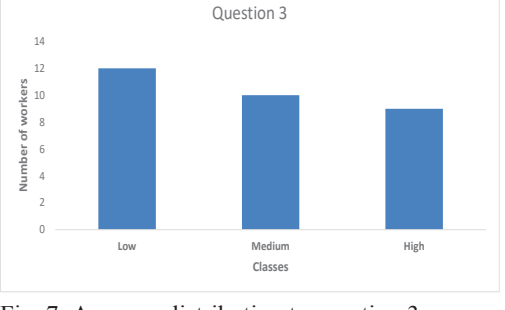

Fig. 7. Answers distribution to question 3.

Figure 7 shows how the reporting of any safety problems, from an unsafe condition to an unsafe act or a safety rule violation is not a common behaviour. The last data gathered during the survey were related to the PPE proper using. Unformal data about the using of the prescribed PPE were collected for two weeks and expressed in Figure 8 as percentage of worker that were using properly the specific PPE prescribed by H&S service and remided by the safety panels.

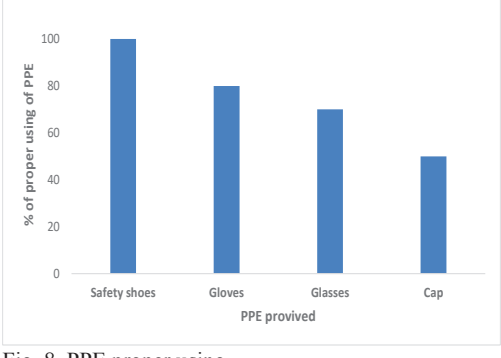

Fig. 8. PPE proper using.

Figure 8 shows how the proper using of PPE changes from "safety shoes", that are dressed by all workers which were prescribed, to the "caps" that were properly dressed by only the 50 % of workers which were prescribed.

4. Conclusions

Results showed in the previous section highlight several information about the relationship between risk as was assessed by H&S managers and risk as it was aware by workers. Comparison of Figures 2 and 3 highlighted a gap between R_g assessed by H&S service and risk perceived by workers. In fact the first distribution was strongly polarized into the second category, the medium one, the second distribution was polarized to the first category (low risk). This gap suggests that workers could have a general attitude of underestimation of the real risk associated to their working activities. Another interesting consideration drives from the comparison between Figure 6 and Figure 8. Workers generally judge as useful the PPE provided to perform in safety condition the working activities but, if they have expressed this kind of thinking why their behaviours were so far away as remarked by the lack of using safety cap and safety glasses? This gap between safety knowledge and safety behaviour marked a strong criticism on the effectiveness of the training process of the safety issues. Some workers that were founded not using the PPE were informally interviewed by researcher with a free dialogue. They generally did not use the PPE when they judged that the working activity was not dangerous. This kind of explanation was in accordance to the consideration previously emerged about the gap between risk assessed and perceived risk. With reference to Figure 7 the distribution of answers related to the third question was the most scattered one. This reveals that there is not a diffusive attitude among workers to communicate to supervisors any circumstances of safety criticality. This situation was fare away from what whished by H&S managers who encouraged a pro-active behaviour. Information acquired with this study highlighted a remarkable gap between safety knowledge and behaviour as imagined by H&S service and as perceived and practised by workers. In addition a not compliant behaviour to safety rules was observed even the importance of safety rules were generally known. As a consequence of these results H&S managers started a revision of their training and communication program, a more participatory approach was suggested with the aim of facilitate the risk awareness among workers.

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