OPERATORS' RISK AWARENESS TOWARDS OPERATIONS' RISK ASSESSMENT: A FIELD STUDY IN THE MOTOR VEHICLE FIELD

Micaela Demichela*, Lorenzo Comberti, Gabriele Baldissone

Dipartimento di Scienza Applicata e Tecnologia, Politecnico di Torino

Corso Duca degli Abruzzi, 24 – I10129 Torino – Italy

Corresponding author e-mail: micaela.demichela@polito.it

Abstract

The purpose of the present research was to verify if, in the motor vehicle industrial domain, an alignment is present between the risk assessed and the risk perceived or if some inconsistencies arise that could affect the safety of the operators. In fact, eventual inconsistencies should be analysed, interpreted, and managed to maximise the information and training process, if needed. The adopted approach in this work relies on the surveying of the operators' perception about the level of risk in a work environment and its comparison with the level of risk assessed by the company. The collection of data was performed through a survey designed ad hoc, distributed to all the workers in the area under study, being them involved in the production and in the maintenance. The survey's structure and aim were described to the operator by the authors and returned by the operators on a voluntary and anonymous basis. The information collected allowed identifying a gap between the risk assessed and the risk perceived by the plant operators. E.g. for the use of personal protective equipment, the data highlighted a discrepancy between the knowledge about their need and the behaviour in using them, that resulted in the revision of both communication and training processes, with the adoption of a more participatory approach. The originality of the work is in the data set, originally collected for this study, in the data collection form, also devised specifically for the case under study, despite it could be easily adapted for other work environment, and in the purpose itself, aimed at pushing risk assessment towards a personalised and adaptive approach.

1. Introduction

As discussed in Lind (2008), industrial maintenance operations expose the operators to several occupational risks due to the various work phases in disassembly and assembly, coupled with the pressure of time and the work in close contact with machineries. The author analysed the data of public Finnish accident reports describing fatal and severe non-fatal accidents in Finnish industry, that involved full-time maintenance workers executing industrial maintenance operations. The examination included the reports refers the years 1985-2004: during the reference periods, a total of 37 maintenance workers died in 33 accident cases. The respective number of victims among severe non-fatal accidents was 90. The analysis of the accidents, both fatal and severe non-fatal accidents, showed that latent conditions and unsafe acts bringing to the accidents were different shortcomings in the planning or performance of work (including conscious risk-taking), even when the involved operators were experienced workers. Other sources of accidents resulted to be typical problems in maintenance operations: time pressure and changing projects and tasks. The increase in automation and the use of more complicated machinery (as the remotely operated ones), together with time pressures arising from customer demands, was also recognised to make safety management in maintenance more challenging. In the same study, it was also acknowledged that, despite the importance of organizational capabilities, the role of workers is critical and has been emphasized in safety management by finding ways to positively affect safe working. In fact, several works have been dedicated to this aspect.

As stated in Rajabali Nejad et al. (2016), operations, safety and humans are critical elements in railway transportation. Thus, building on the work from previous authors, that found a 17% increase in the prevalence of safe behaviour and a 57% reduction in injury frequency in an implementation of peer-to-peer feedback at a major freight carrier within the railroad industry, Ranney et al. (2018) analysed the effectiveness of peer-to-peer feedback safety methods (PPF) use to identify and address at-risk behaviours before they trigger injuries by using worker-to-worker observations of work behaviour, conditions and organizational factors and the related feedback.

Liang et al. (2010) proposed a technical solution to increase aviation maintenance and inspection safety, an on-line maintenance assistance platform (on-line MAP) for technicians to perform maintenance tasks. In this platform, the risk of human error was defined in each task procedure to prevent it and improve satisfaction with the job. A subjective questionnaire survey, addressing maintenance behaviour, issues related to the on-going activity, performance shaping factor (PSF) investigation, and mental workload, an objective performance measure (expert evaluation and situation awareness), and time performance were collected and analysed to quantify the human errors, as a human error impact risk index (IRI). The results, from 42 participants, revealed that teams' risk cognition, situation awareness, technicians' performance and their job satisfaction have all been increased by the proposed on-line tool with respect to the traditional instruction system.

Furthermore, as detailed in Lee et al. (2012), situation awareness (SA) is frequently cited as a key to effective and efficient performance, considering that SA determines the ability to initiate correct actions given a particular situation and to respond properly to system feedback. This is recognised both for single operators as for operators' teams. For the teams, the communication is recognised to be a critical factor for situation awareness. As discussed in Naderpour et al. (2014), situation awareness encompasses the perception of elements in the environment, the understanding of their meaning, and the projection of the status of that environment after a while. Situation awareness is expected to be at the root of many accidents in safety-critical environments where multiple goals must be pursued simultaneously, multiple tasks require the operator's attention, operator performance is under high time stress, and negative consequences associated with poor performance are anticipated. These characteristics are typical of the maintenance operations, even if not in safety-critical environments. The recent study of Illankoon et al. (2019) showed how active errors in aircraft physical deviations can propagate from the latent conditions of maintenance process deviations. The authors identified attention, memory errors and inadequacy of processes and documentation as major causal factors, and conclude SA interventions are invaluable to treat judgemental errors, improve procedures and communication, and leverage awareness to capture latent erroneous conditions, and, more specifically, they show how situation awareness (SA) interventions can assist in the mitigation of maintenance deviations and capture hidden causal factors.

When operator or asset safety is concerned, regulations and standards discipline the safety management as designed on risk assessment. As discussed in Demichela et al. (2018), the hazard identification and related risk assessment phases, related to all the working activities, including maintenance operations, are transferred to the operators thanks to the information and training activities. Within the factors influencing the loss of significance during the information and training process, the gap between risk perception of managers compared to workers risk perception was identified as relevant (Arboleda et al., 2003). Despite, even workers trained and equipped to work in safe conditions not always follow safety rules (Leva et al., 2018).

Some authors identified the conflict between workers and managers as a common case of low compliance (Baldissone et al., 2018), others highlighted the role of personal experience (Slimak et al., 2006) where workers who have personally experienced the consequences of an 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).

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 its different definitions (He et al., 2012) were identified as crucial to gain good safety awareness and performances (Huang et al., 2006). The constructs used to assess them have varied from study to study, as summarised in Comberti et al. (2020). On the other hand, as stated in Oah et al. (2018) the influence of safety climate, safety leadership, workload and accident experience on risk perception is an extremely complex multilevel factor, playing a critical role in predicting individual risk behaviour in the manufacturing domain.

This paper outlines some of the results of a wider field study performed into a motor vehicle plant aiming at analysing the relationship between risk assessed by Safety experts and risk awareness in operators. Section 2 of this paper describes the methodology used to carry on this study and section 3 provides some relevant results. Conclusions discuss the results and close the paper.

2. Materials and methods

This work was carried on into a motor vehicle assembly-plant where significant efforts in term of safety improvements have been made; production and maintenance are integrated processes in the work environment. The plant is organized as a series of assembly lines composed by a sequence of working-stations where operators and maintainers are assigned, while the vehicle is moved automatically from a workstation to the next. Each task, according to the specific operation and tool used, exposes operators to different risks: from ergonomic to operational.

To investigate the relationship between risk assessed and operators risk awareness, an assembly line of 26 working stations involving 50 workers was selected.

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.

The assessment of the risk perceived by the workers was carried on through a survey consisting in a set of questions related to risk perception and safety rules evaluation.

To make a comparison possible, it was necessary to develop a common scale of evaluation (Gerbec et al, 2017).

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 technological risk expression:

$$R = P \times S \qquad (1)$$

Where the risk, R is simply function of the probability of occurrence of the unwanted event, P, and of its potential severity in terms of consequences, S. The hazards considered include all the mechanical, chemical, ergonomic, lay-out and physical factors (noise, temperature, radiation, etc.) that can affect the operator in each single workstation.

P and S values were estimated for each hazard factor using a numerical scale from 1 to 4, whose meaning has been made explicit in order to limit the effect of subjective evaluations. As a result each working station, and related activity, was characterized by a number of risks with a value included between 1 and 16.

A global risk index “Rg” was then assigned to each workstation summing up all risks’ indexes related to the single hazard pertaining the working station, according to equation 2.

$$R_g = \sum_1^n P_i \times S_i \qquad (2)$$

Where *i*, varying from 1 to n, represent the i-th hazard present in the workstation.

Figure 1 summarises Rg values for the assembly line selected as case study.

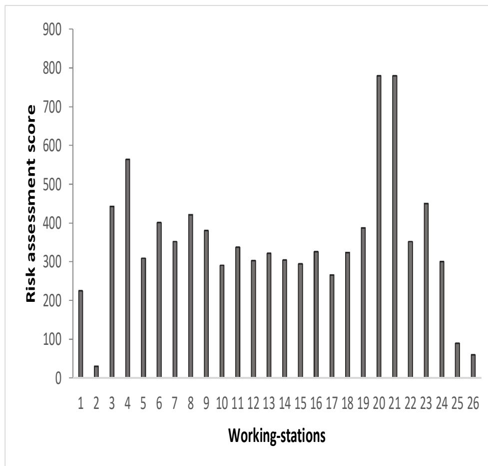

Fig. 1. R_g index for the working-stations.

Even if the working stations are components of the same assembly line the Rg 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 the assessed Rg and the level of risk perceived by the operators, Rg values were re-calibrated to a 3 level scale where:

- Rg from 0 to 200 was scaled to 1;
- Rg from 200 to 400 was scaled to 2;
- Rg 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 understanding of the risk assessment of the whole assembly line.

2.2 Perceived risk level

The risk perception information was obtained through a questionnaire distributed to the operators. 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 expressing 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?		
	Low	Medium	High
2	Is it easy to identify the hazards you are exposed to during the working activity?		
	Lowly (Low)	Moderately (Medium)	Highly (High)
3	To what extent do you report to your supervisor any safety problem?		
	Low	Medium	High
4	PPE provided for your working station are useful?		
	Lowly (Low)	Moderately (Medium)	Highly (High)
5	Safety panel and safety visual warnings are useful during the working activity?		
	Lowly (Low)	Moderately (Medium)	Highly (High)

Workers were asked to answer to each question with a scale from 1 to 3, with 1 being low, 2, medium and 3 high.

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

Adopting a common scale of evaluation allowed a direct comparison between the results of the two aspects: the risk assessed, and the risk perceived.

3. Results

Results obtained from the scaling of the Rg values (Figure 1) were summarised in Figure 2. Rg 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 Rg distribution was strongly polarized in "medium" class, that included most of the working stations. 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".

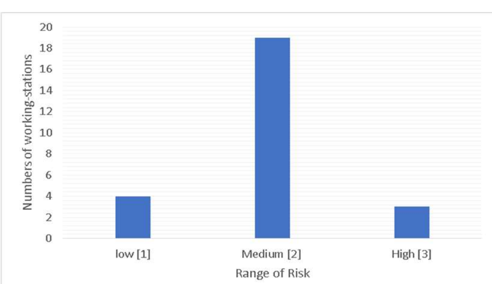

Fig. 2. Results of workstations Rg re-scaling

Rg values provides a quantification of risk which each worker is exposed to during his own working activity, depending on the working station. This information was transferred to the worker by the H&S service, through information and training and assigning to each operator a specific set of PPE and safety procedure. To verify 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 "Which is the level of risk of your working station?" of the questionnaire (Table 1). Figure 3 summarises this result and it shows how the distribution of worker's perception of risk associated to working-station is strongly focused on the "low" category, this highlighting a general underestimation of the risk level.

It has to be noticed that anonymous replies to the survey did not allow linking the questionnaire to a specific workstation, consequently the results discussed in the following section descend from the analysis of aggregated survey's replies over the production line.

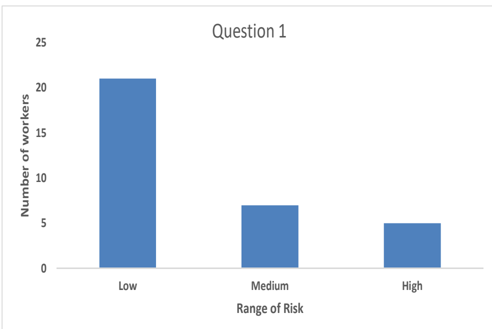

Fig. 3. Risk related to working-station as perceived by workers.

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

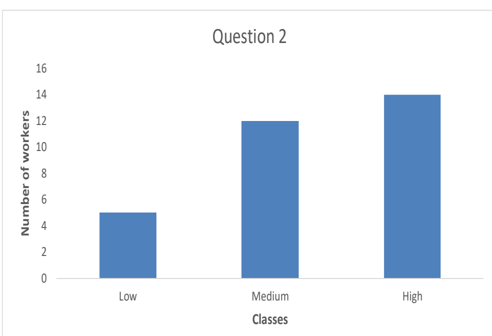

Fig. 4. Answers distribution to question #2 'Safety panel and safety visual warnings are useful during the working activity?' .

In particular Figure 4 highlights how workers find it easy to identify hazards in their working station during the working activity. This result seems to be in accordance to the 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.

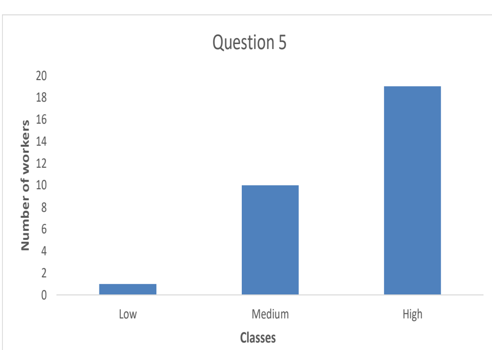

Fig. 5. Answers distribution to question #5 “To what extent do you report to your supervisor any safety problem?”

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

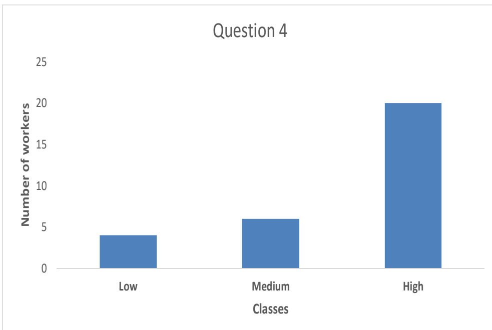

Fig. 6. Answers distribution to question #4 “PPE provided for your working station are useful?”

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.

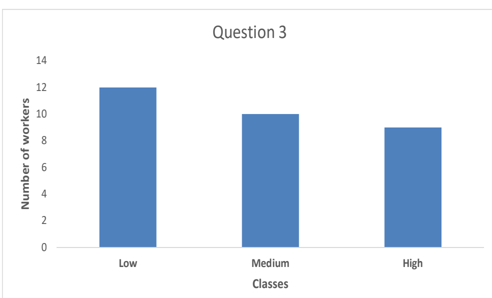

Fig. 7. Answers distribution to question #3 “To what extent do you report to your supervisor any safety problem?”

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 behavior.

The last data gathered during the survey were related to the PPE proper use. 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 reminded by the safety panels.

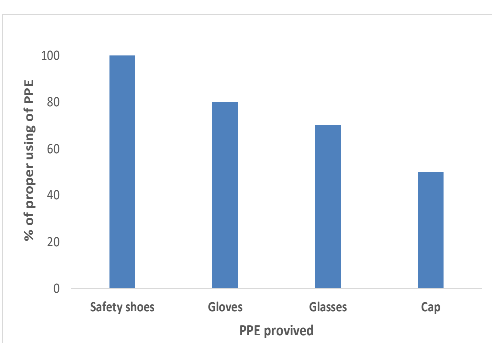

Fig. 8. PPE proper using.

Figure 8 shows how the proper use 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 to.

4. Conclusions

Data collection programs such the one proposed in this paper are recognized to provide a real-time review of current safety issues in operations and maintenance (Clancy et al, 2011). Real-time data review facilitates the identification of areas where modifications to working practices, equipment, training programs or standard operating procedures might be appropriate and allow relating the interventions to the operator risk perception (Douglas et al., 2015)

In this case, results showed in the previous sections highlight several information about the relationship between risk as it was assessed by H&S managers and risk as it was perceived by operators. Comparison of Figures 2 and 3 highlighted a gap between Rg assessed risk perceived. 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 underestimate the 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, despite their thinking, their behaviour is not coherent 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 about 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 their working activity as not dangerous. This kind of explanation was in accordance with 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 far 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. Because 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 facilitating the risk awareness among workers.

In general, the results obtained by the study highlight how both in production and maintenance, above all for the sake of safety and the minimisation of occupational and operational accidents, it is important to enhance the participation of the operators in order to verify the effectiveness in the transmission of information related to risks and their management, and ultimately in the safety awareness can be reached across the operators.

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