Safety Science 79 (2015) 175–183

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Proactivity-and-consequence-based safety incentive (PCBSI) developed with a fuzzy approach to reduce occupational accidents

Ada Saracino [a], Matteo Curcuruto [b], Giacomo Antonioni [a,*], Marco Giovanni Mariani [b], Dina Guglielmi [c], Gigliola Spadoni [a]

[a] Department of Civil, Chemical, Environmental and Materials Engineering (DICAM), University of Bologna, Via Terracini 28, 40131 Bologna, Italy
[b] Department of Psychology, University of Bologna, Viale Berti Pichat, 5, 40126 Bologna, Italy
[c] Department of Education Sciences, «Giovanni Maria Bertin», University of Bologna, Via FIlippo Re 6, 40126 Bologna, Italy

ARTICLE INFO

Article history:
Received 18 November 2014
Received in revised form 3 June 2015
Accepted 12 June 2015
Available online 26 June 2015

Keywords:
Occupational safety
Proactivity
Safety incentive
Fuzzy inference system
Reward system

ABSTRACT

This study introduces a new reward system for enhancing safety during work activities, by improving workers' motivation in performance and thereby reducing occupational accidents. The reward system is based on a safety incentive that can be defined by means of two parameters: the worker behavior, which is measured especially in terms of proactivity (namely workers' attitude in reporting potentially hazardous situations) and the consequences that could be avoided thanks to the reporting activity. In doing this, the fuzzy logic theory can be usefully applied, because it offers the opportunity to quantify the two parameters taking into account their vagueness, through the concept of degree of membership and then it also allows to combine them into the final value of the safety incentive through a Fuzzy Inference System (FIS). The model, named "Proactivity-and-Consequence Based Safety Incentive" (PCBSI), has been tested in an Italian chemical plant, with the purpose to evaluate its effectiveness.

1. Introduction and background

Human factors, risk perception and workers' behavior play a very important role in the occurrence of accidents (e.g. Reason, 1997); Griffin and Neal (2000) argued that safety motivation also plays an important role as a precursor of safety behavior, since the term "safety motivation" refers to an individual willingness to exert effort to enact safety behaviors. Thus employees should be motivated to work in a safe manner and to participate in safety activities.

One of the most important tools for improving workers motivation is a reward distribution system, whose correct definition and implementation could decrease the occurrence rate of occupational accidents. As a matter of fact, different studies have shown the relationship between lost workdays, time loss for injuries, accident costs and the use of incentives and of feedback to improve safety: e.g. Haines et al. (2001) observed that incentives are associated with a number of positive outcomes (e.g. reduction of accidents). Other similar studies (McAfee and Winn, 1989) found that incentives and feedback successfully improve safety conditions or reduce accidents. Thus a safety reward system has to be considered as an important aspect of company organization (Griffin et al., 2014).

The importance of employees' participation has been recognized as a fundamental aspect of safety performance in organizational settings (Griffin and Neal, 2000) and a commitment-based (or participative) approach in safety promotion should be based on a proactive worker contribution and it goes beyond a simple compliance-based passive contribution (Barling and Hutchinson, 2000).

On the basis of these considerations, in this work a correlation between workers' participation and a safety reward system is proposed; the correlation is based on a specific kind of participatory contribution by workers in safety promotion, which can be considered a form of proactivity, and which can be measured for instance through the spontaneous risk-reporting activities by the employees. Reporting activities can be translated into the risk perceived by workers, who can produce a risk-report spontaneously when he/she observes damages, malfunctions, hazards or an unsafe work condition in the surrounding environment. But each situation could have a different degree of hazard, thus information gathered from a report can also help in the evaluation of the hypothetical damage that the observed situation would have caused.

If reports are assessed on the basis of their quality in terms both of proactivity and of potential consequences, the company may

* Corresponding author. Tel.: +39 0512090230; fax: +39 0512090247.

http://dx.doi.org/10.1016/j.ssci.2015.06.011
0925-7535/

obtain benefits from this kind of workers' participation such as avoided damages, decreased accidents and improved safety. Therefore, a worker who produced a good report both in terms of proposed solutions to the problem and of importance of the avoided hazard should be rewarded by the company for his/her behavior through an incentive (not necessarily economic).

The proposed method, which has been called PCBSI (Proactivity-and-Consequence Based Safety Incentive), can be seen as a new approach for enhancing safety in workplaces and consequently for reducing the costs of accidents for the company and, beyond the definition of a safety incentive, this tool could also be useful for a systematic assessment of the reports.

In order to achieve this goal a multidisciplinary approach was required for two main reasons: firstly in order to investigate the use of techniques for behavior modification to improve safety and to understand the effect of workers' participation; secondly, in order to define a measure for the parameters of the model through the application of the fuzzy logic theory, thanks to its ability in facing uncertainty and vagueness typical of human behavior. Thus, in this study, both engineering and psychology approaches have been conveniently applied in order to develop a method that can enhance occupational safety.

2. Theoretical framework

Theoretical aspects of proactivity will be discussed hereinafter since they are the starting point for the definition of the assessment procedure. Then a specific methodology to quantify the consequences will be introduced, and finally a brief review about safety incentives and about the aspects related to their influence on the health and safety performance will be described.

2.1. Key-attributes of proactive behavior

In conceptualizing key attributes of proactive behavior in occupational safety domain, three general features, recognized in organizational literature, can be identified (Parker and Collins, 2010): proactive behavior by individuals refers to self-initiated, anticipatory and taking charge of the improvement of the workplace.

Firstly, proactive behavior by employees does not need to be formerly prescribed to be enacted, nor it requires detailed instructions or requests, therefore it could be conceptualized as self-started and self-determined. Despite the impossibility to predict in advance every form of risk factor in a complex work environment, participative behaviors are strongly recommended by managements. Self-started initiative by operators may become essential when standardization does not sufficiently cover all possible situations and could lead to threats for safety.

Secondly, a proactive behavior should be anticipatory and future oriented and implies to act in advance to a future situation, rather than just reacting to solve contingent problems or adjusting to an unpredictable situation. This second attribute of proactivity underlines an implicit performance dimension by safety management systems in organizations, which becomes relevant if high reliability safety conditions over time should be held (Weick and Sutcliffe, 2011).

Thirdly, proactive behaviors are intrinsically meant to create improvements to the actual work and organizational situation and to make things happen rather than just waiting for something to happen for the initiative of someone else. As argued by Morrison and Phelps (1999), "taking charge" entails voluntary and constructive efforts, by individual employees, to effect organizationally functional change with respect to how work is executed within the contexts of their jobs, work units, or organizations.

2.1.1. Degrees of proactivity in risk-reporting

These three typical attributes were considered in order to develop a measure of proactive behavior in risk reporting within occupational safety. Specifically two theoretical frameworks have been selected as starting points in order to define different levels of proactivity: the model of Parker and Collins (2010) on attributes of proactive behavior and the model of Hollnagel et al. (2011) on safety resilience capabilities. Both theoretical models developed a rating scale (reported in the 2nd and 3rd column of Table 1), starting from these scales and considering the key attributes of proactivity, a new behaviorally anchored rating scale, ranging from one to five, has been developed for proactivity (first column of Table 1).

Since in organizational behaviors, proactive ones are characterized by being self-started, anticipatory and taking charge (Parker and Collins, 2010), being the latter the most important because it can generate improvement and a generalized learning, as argued by Griffin et al. (2007), proactivity must not be only "taking charge", but it must also create a visible impact. Thus in this study the "taking charge" attribute is further splitted into two levels, so that the first include the actions that create a generalized impact in terms of change and actual improvement of workplace safety (level five) and in the second only the actions limited to "taking charge" are considered (level four). Then, since both anticipation and learning are considered typical elements of proactivity in ergonomics (Hollnagel et al., 2011, 2006), intersecting ergonomics and organizational behavior, the aspect of learning is implicitly considered as a vehicle for positive change, while the anticipation element (level

Table 1
Degrees of proactive participation in risk management: conceptual foundations and paradigm comparison.

Types of risk-reporting: Proactivity levels of workforce participation in risk management	**Attributes of proactive behavior** (see Parker and Collins, 2010)	**Safety resilience capabilities** (see Hollnagel et al., 2011)
Level one Spontaneous reporting activities of contingent risk factors in the workplace	**Spontaneousness** Low proactivity **Self-started** Undertaking a course of actions without no need to be asked to act	**Monitoring** (*addressing the critical*) monitoring what happens, and recognizing if something changes to affect the operative abilities
Level two Self-started problem solving to correct current discrepancies from the standards		**Responding** (*addressing the actual*) reacting to regular and irregular variability and disturbances,
Level three Anticipatory problem prevention related to the possible future consequences of risk factors	**Future-oriented** Acting in advance of a future situation, rather than just reacting	**Anticipating** (*addressing the potential*) envisioning developments that lie further into the future, beyond the current operations
Level four Initiatives and suggestions for safety improvement of the current risk management	**Taking-charge** Taking control and causing something to happen, rather than just adapting or waiting for something to happen	**Learning** (*addressing the factual*) Improving future performance experimenting changes as results of new experiences
Level five Generalization of the stimulated improvement in the broader organization setting	**Observable improvement outcomes**	–