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Safety performance evaluation in a steel industry: A short-term time series approach

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ABSTRACT

Background: The aim of the present study was to assess the safety performance in a steel industry and predicting the occurrence of incidents using Customized Predictive Risk Index (CPRI) technique.
Materials and methods: 350 unsafe observations were recorded and scored based on risk factors of probability of danger, frequency of work exposure, number of persons at risk, and severity of consequence. Risk Index (RI) of each observation was calculated through geometric average of risk factors. Optimum forecasting time series model of RI was determined using the smallest value of Akaike information criterion (AIC) to predict the CPRI trend and forecast the occurrence of incidents with a 95% confidence interval. Descriptive analysis was conducted using SPSS 22.00 and incident forecasting based on CPRI trend was conducted using forecast package for R 3.3.1.
Results: Autoregressive of 6 consecutive observations (AR-6) was chosen as the optimum model to fit time series data and define CPRI (AC = 1226.58). Most incidents occurred when the CPRI value was exceeds five and this range was determined as action zone and forecasting criteria for predicting the occurrence of incidents.
Conclusion: Customized Predictive Risk Index (CPRI), developed in this study could be used as a leading indicator for safety performance in steel industry. Ensuring the managers about the functionality of leading indicators to assess safety performance could be facilitated with comparing the results achieved by models with the real data.

1. Introduction

Workplace safety is essential in preventing or reducing the risk of workplace injury, illness and death. By considering safety in production, employers can not only protect their employees and prevent incidents from occurring, but also can increase the productivity and reduce the costs of work related sickness, absenteeism, poor management strategies and performance reduction (Boksem and Tops, 2008; Fruggiero et al., 2016). An unexpected event caused by an unsafe act or an unsafe condition (UAUC) disrupts, or has the potential to disrupt, the workflow of an industrial process, regardless of whether or not the event actually causes injury or property damage (Jones et al., 1999).

Safety performance evaluation is defined as a set of actions implemented to measure the effectiveness of safety procedures adopted by an organization (Brauer, 2016). The emergence of new regulations and international standards have forced organizations to augment their safety performance (Santos-Reyes and Beard, 2002). Assessing the safety performance of any process by means of proper and relevant indicators is of great necessity (Pasman and Rogers, 2014). A safety performance indicator is a functional and computable variable that can be employed for explaining the safety performance status in an industry (Øien, 2001). Safety performance indicators can be divided into lagging and leading indicators (Reiman and Pietikäinen, 2012). The lagging indicators such as accident statistics are passive and do not have the ability to predict the possible incidents (Brauer, 2016; Chen and Yang, 2004) and assessing the consequence of activities or events that have already occurred (Reiman and Pietikäinen, 2012). There have been a great acceptance of the fact that the failure-based measures are not very

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useful in aiding organizations to drive continuous safety efforts. However, considerable amounts of Occupational Health and Safety (OHS) initiatives are still being evaluated by relying primarily on lagging metrics, such as fatality and injury rates (Sinelnikov et al., 2015).

Several attempts have been made to develop more effective methods, including leading indicators, in assessing the safety performance of an organization (Chen and Yang, 2004). These indicators are used to discover and monitor the potential occurrence of incidents and give essential feedback on their prevention (Reiman and Pietikäinen, 2012; Leveson, 2015; Ahmad, 2000; Kjellén, 2000). A group of leading indicators are based on recording and analysis of UAUC, as they play vital roles in the occurrence of catastrophic incidents. Although UAUC may not immediately result in an accident, they could be used as an indicator for safety performance evaluation and their potential outcomes should be considered as a predictive safety measure (Chen and Yang, 2004).

Most of leading indicators only evaluate the current safety performance of an organization and fail to predict the occurrence of incidents (Chen and Yang, 2004; Øien et al., 2011). In a study conducted by Chen and Yang (2004), a model titled predictive risk index (PRI) was developed based on observation of UAUC in a petrochemical plant. According to the results of this study, the PRI trend successfully matched with several incidents and provided a warning indicator for monitoring the current safety performance in the plant (Fig. 1). However, long term observation of unsafe observations is not possible for all industries especially for industries with poor safety management. Moreover, this model has been developed only in process plants and it should be studied in other industries with different potential hazards. Additionally, risk factors and their scoring system and also PRI levels (safe, warning and action levels) should be defined and adjusted for each industry.

In view of the aforementioned statements, this study aimed to assess the safety performance in a steel industry and predict the occurrence of incidents using Customized Predictive Risk Index (CPRI) technique.

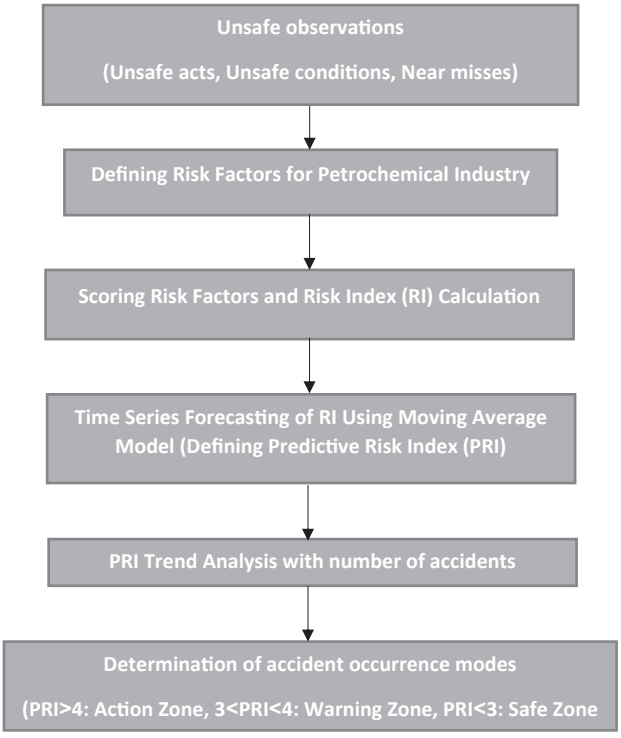

Fig. 1. The flowchart of Predictive Risk Index (PRI) for petrochemical industry developed by Chen and Yang (2004).

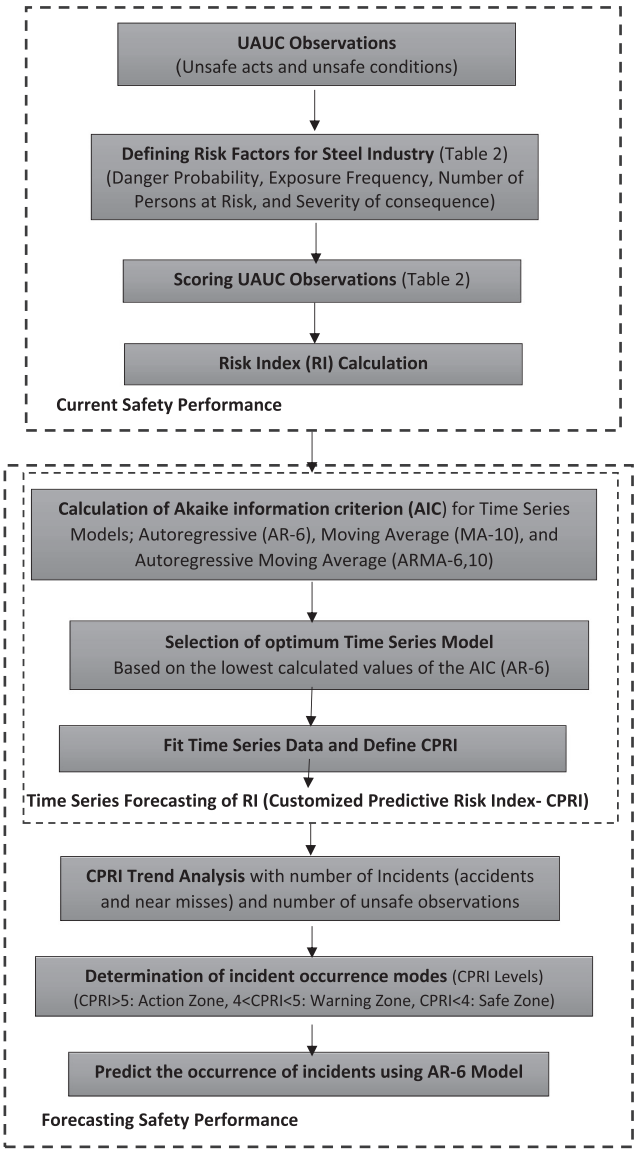

Fig. 2. The flowchart of Customized Predictive Risk Index (CPRI) for steel industry plants developed in this study.

2. Materials and methods

This descriptive study was conducted in a steel industry in Iran, in 2016. Steel manufacturing is among the important and high risk industries and studies have demonstrated that steel workers are faced with many risks due to the dangerous nature of their duties, and have thus experienced more accidents compared to other workers (Barreto et al., 1997; Nordlöf et al., 2015). Despite the improvement of the safety conditions of furnaces in steel industries over the years, inherent dangers in working close to molten metal still exist (Von Starck et al., 2005). Therefore, safety performance evaluation and predicting the potential risks in this industry is very important for taking proactive measures to prevent probable incidents (Chen and Yang, 2004).

The safety performance was assessed using PRI technique, which was customized for steel industry and named CPRI in this study (Fig. 2). This technique predicts the occurrence of incidents based on time series data of Risk Index (RI) of the observation of UAUC (Chen and Yang, 2004). In this study, safety performance was measured using CPRI technique because it incorporates the UAUC which are the causes of accidents, according to the Domino accident theory (Brauer, 2016).

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