



Contents lists available at ScienceDirect

# Safety and Health at Work

journal homepage: [www.e-shaw.org](http://www.e-shaw.org)

## Original Article

# Investigating the Impact of Establishing Integrated Management Systems on Accidents and Safety Performance Indices: A Case Study

Fereydoon Laal<sup>1</sup>, Mostafa Pouyakian<sup>2</sup>, Rohollah F. Madvari<sup>3</sup>, Amir H. Khoshakhlagh<sup>4,5</sup>, Gholam H. Halvani<sup>6,\*</sup>

<sup>1</sup> Student Research Committee, Department of Occupational Health, School of Public Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran

<sup>2</sup> Department of Occupational Health Engineering, School of Public Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran

<sup>3</sup> Research Center for Environmental Determinants of Health (RCEDH), Kermanshah University of Medical Sciences, Kermanshah, Iran

<sup>4</sup> Department of Occupational Health, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

<sup>5</sup> Students' Scientific Research Center, Tehran University of Medical Sciences, Tehran, Iran

<sup>6</sup> Department of Occupational Health, School of Public Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran

## ARTICLE INFO

### Article history:

Received 20 October 2017

Received in revised form

24 February 2018

Accepted 5 April 2018

Available online 17 April 2018

### Keywords:

Integrated management systems

Occupational accident

Power plant

Safety performance indices

## ABSTRACT

**Background:** Increasing the establishment of integrated management systems (IMs) is done with the purpose of leaving traditional management methods and replacing them with modern management methods. Thus, the present study sought to analyze the events and investigate the impact of IMs on health and safety performance indices in an Iranian combined cycle power plants.

**Methods:** This case study was conducted in 2012 in all units of the Yazd Combined Cycle Power Plant on accident victims before and after the implementation of IMs. For data analysis and prediction of indices after the implementation of IMs, descriptive statistics and Kolmogorov–Smirnov test, Chi-square, linear regression, and Cubic tests were conducted using SPSS software.

**Results:** The number of people employed in the power plant in an 8-year period (2004–2011) was 1,189, and 287 cases of work-related accidents were recorded. The highest accident frequency rate and accident severity rate were in 2004 (32.65) and 2008 (209), respectively. Safe T-score reached to below –3 during 2010–2011. In addition, given the regression results, the relation between all predictor variables with outcomes was significant ( $p < 0.05$ ), except for the variable  $X^1$  belonging to the accident severity rate index.

**Conclusion:** The implementation of safety programs especially that of IMs and its annual audits has had a significant impact on reducing accident indices and improving safety within the study period. Accordingly, health and safety management systems are appropriate tools for reducing accident rate, and the use of regression models and accident indices is also a suitable way for monitoring safety performance.

© 2019 Occupational Safety and Health Research Institute, Published by Elsevier Korea LLC. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## 1. Introduction

Occupational health and safety has become an important issue in all industries and occupations along with a rapid growth of industries and technology. Occurrence of occupational damages and diseases has considerably reduced after scientific and technological changes and the establishment of occupational health and safety management systems [1,2]. In recent years, the role of occupational health and safety management as a strategic key and a tool to help improve health in workplace in long run and reduce the cost of work has been mentioned [3]. However, industries are known as high-risk environments and impose high costs on human health because of accidents and occupational diseases [1,2]. According to

the figures, current work-related accidents are regarded as the third most common cause of death in the world, the second cause of death in Iran, and one of the main health, social, and economic risk factors in industrialized and developing communities [4]. The average rate of work-related deaths worldwide is 14 [5], 23.1 in the continent of Asia, and 5.89 in the United States of America per 100,000 workers [6]. In most workers, occupational injuries restrict activities, whereas in some cases, they lead to job change [7].

Miller et al (1997) investigated accidents and quantitative modeling of resulting costs and showed that preventing accidents is one of the effective ways to reduce costs and increase productivity [8].

Safety programs are effective factors in the productivity of labor force and promoting production qualitative and quantitative indices,

\* Corresponding author.

E-mail address: [halvani39@gmail.com](mailto:halvani39@gmail.com) (G.H. Halvani).

which play a large role as one of the major indices of productivity and production [9]. Nowadays, organizations attempt to improve their services. To this end, management systems and standards play key roles in different industries. One of these management systems is the combined system of quality, health, safety, and environment [10]. To achieve better performance, organizations have implemented quality management systems and health, safety, environment, quality management system. Such organizations have developed an integrated management system (IMS) that includes ISO-9001, ISO-14001, and OHSAS18001 to access and store their resources that are universally accepted [11,12]. Among these standards, OHSAS18001 standard focuses on safety and health issues. This standard considers the planning of health and safety policies for identifying risks and hazards and controlling measures for occupational accidents [13]. In a study aiming at the investigation of safety, health, and environment management status in EU members, Duijm et al concluded that industries mostly attempt to implement HSE-based plans for more success and profitability. They also referred to the positive role of HSE management in the development of safety performance and accident control indices [14]. Eleonora Bottani et al also showed better safety status in industries in which a safety management system is accepted and updated [15]. In a study by Hamidi et al aiming at the investigation of the effect of an IMS on safety and productivity indices in cement industry during 2005–2010, it was found that there is a significant relationship between different safety indices before and after the implementation of the system [16]. Findings of Omidvari et al indicated a significant relationship between safety plan implementation and accident indices. That is, frequency rate, severity rate, and frequency–severity index were reduced due to impact of safety programs [9]. Similarly, Fernández-Muñiz et al studied the relationship between occupational safety management and company performance. Their findings showed that safety management has a positive impact on safety performance, competitive performance, and economic–financial performance [17]. Gilberto Santos et al concluded that small- and medium-sized Portuguese companies obtained benefits from the certification of occupational safety and health management systems such as improving working conditions, ensuring compliance to regulations and rules, and better communication about risks and dangers [18]. Hence, given the significance of IMS and investigation of its role, it is better to conduct more studies for its progress in the industries.

One of the most important and vital industries in Iran in the field of power generation is Yazd Combined Cycle Power Plant with a nominal power of 993.8 MWh and an area of 9 km<sup>2</sup>, which has been established to meet the growing demand of Yazd province and large industries such as electrical steel to electrical energy [19].

Briefly, a combined cycle power plant uses gas and steam turbine engines in combination to produce power. The generator of gas turbine generates electricity, and the waste heat from the gas turbine is used to generate the steam required for steam turbine. In this way, additional electricity is produced [20].

With regard to the review of the related literature, there is a dearth of research focusing on accidents in combined cycle power plants or at least their report is not available in the sources. Thus, the present study was conducted aiming at investigating the role of establishing an IMS on accident and safety performance indices in Yazd Combined Cycle Power Plant.

## 2. Material and methods

### 2.1. Research type and sample

This research was a case study that was conducted in 2012 in two stages in all units of Yazd Combined Cycle Power Plant on accident victims (287 cases) in 2004 (before the implementation of

IMS) and 2005–2011 (after the implementation of IMS). Yazd power plant is a combined cycle type that includes a number of gas and steam turbines. The fuel used in the combined cycle power plant of Yazd is natural gas and gas oil or a combination of them [19]. The study units included are repairs and maintenance, chemistry and refinery, exploitation, technical and engineering, vehicle and support, and protection units, which are briefly described in the following.

The repair and maintenance unit is carried out to check the existing situation and to upgrade and maintain the equipment at favorable conditions so that the erosion of the equipment and, as a result, heavy costs of purchasing and repairing parts for the set will be minimized. In the Yazd Combined Cycle Power Plant, owing to the use of wastewater in the water and steam cycle and the cooling tower unit, this industry is one of the most consumable industries in terms of water resources management. To prevent corrosion and other deterioration factors, the water required is purified by the chemistry and refinery unit. The water purification steps include introductory steps such as chlorination and reverse osmosis filtration and a deionization system. The plant consists of two Kraft units and S1 and S2 blocks. The S1 block consists of two gas units and one steam unit, which were manufactured by (Alstom, France) and (Siemens, Germany) companies respectively. The S2 block also includes two gas units and one steam unit, which were built by (Ansaldo, Italy) and (Siemens, Germany) companies, respectively. These units are subunits of exploitation. The tasks of the technical and engineering department include the design and examination of the maps, eliminating defects, etc. The vehicle and support unit is also responsible for the handling of personnel and procurement matters. In addition, the protection unit provides security and protects facilities, buildings, and operational forces [19].

In the meantime, during this study period, there was no significant change in the technology of the power plant.

Sampling was done as total counting. The variables studied included working hours, lost workdays, and accident indices [accident frequency rate (AFR), accident severity rate (ASR), frequency–severity index (FSI), and Safe T-score (STS)].

### 2.2. Data collection method and tool

At the beginning of the work, after the required coordination, a committee composed of experts in the implementation of IMS, senior managers of the organization, and the researcher was formed. Then, primary information was extracted through a questionnaire and interview with accident victims (using event reminder technique) in the years after IMS implementation. Accidents that led to the loss of a day or a shift in work and more were evaluated as work-related accidents. Most of the workers are insured by Iran's social security administration. According to the rules of this organization (Article 60), work-related accidents are those that occur to the insured worker during performance of the duties (work activity). During performance of the duties means all the time that an insured person is working inside the workplace or outside the workplace area by the order of their employer. Meanwhile, travel times from home to the workplace or vice versa are also considered at the mentioned time. Accidents that occur during the act of rescuing other insured persons will be considered a work-related accident as well [21].

### 2.3. Accident indices

AFR, ASR, FSI, and STS indices were calculated (Equations (1)–(4)) based on the Occupational Safety and Health Administration (OSHA) standard [22]. To homogenize accident frequency in terms of functional time, frequency rate index was used, and because each

accident with more lost days is more severe, ASR was used for expressing the accident severity. The calculation of this index, when the accident causes permanent disability, death, or paralysis, is obtained using OSHA missing days' table in terms of injury type. The FSI is also a way to interact with these two methods, which provides a more reliable basis for evaluations. Moreover, the rates of these indices were calculated in different working units, including repairs and maintenance, chemistry and refinery, vehicle and support, exploitation, technical and engineering, and protection units in different years.

$$AFR = \frac{N \times 200000}{T} \quad (1)$$

$$ASR = \frac{n \times 200000}{T} \quad (2)$$

$$FSI = \sqrt{(AFR \times ASR)/1000} \quad (3)$$

$$\text{Safe T - Score} = \left\langle AFR_{\text{new}} - AFR_{\text{old}} \left| \frac{\sqrt{AFR_{\text{old}}}}{200000} \right. \right\rangle \quad (4)$$

N: number of accidents in a specified time,  
n: number of lost workdays due to accidents in a specified time,  
T: total efficient working hours of the workers in that specified time,  
t: total efficient working hours of the workers in new year.

In addition, the STS was used for the analysis of status and significance, which is investigated for comparing two statuses (before and after), and the results were interpreted using Table 1. Using frequency rate, STS index is used for expressing the improvement or nonimprovement of safe conditions. According to Table 1, if the STS is less than  $-3$ , safety condition of the combined cycle power plant has improved ( $STS < -3$ ).

#### 2.4. Prediction of accident indices

After obtaining descriptive data and accident indices in different years, the results of Cubic or Grade 3 regression model were used to predict these indices in the years after the implementation of IMSS in this industry. It should be noted that predictive models in various industries may be different. Cubic model equation is as follows:

$$Y = \beta_0 + \beta_1 X^1 + \beta_2 X^2 + \beta_3 X^3 \quad (5)$$

X: the predictor or independent variable ( $X^1$ ,  $X^2$  and  $X^3$ ).  
Y: the outcomes or dependent variable (Indicators: AFR, ASR, and FSI).  
 $\beta_0$ ,  $\beta_1$ , and  $\beta_3$ : coefficients.

Regardless of the  $\beta$  mark (+ or  $-$ ), the more the value of  $\beta$ , the stronger the relationship between the predictor variables ( $x^1$ ,  $x^2$ ,

and  $x^3$ ) and the related outcomes. For each predictor variable, the value of P is separately obtained. If the value of P is less than 0.05, then it is significant.

#### 2.5. Statistical analyses

After data entry in SPSS version 19, descriptive statistics were used to describe some data, and Kolmogorov–Smirnov test, Chi-square test, linear regression test, and Cubic tests were carried out for data analysis. In this research, as mentioned, the significance level was considered equal to 0.05. Finally, scientific solutions were proposed for monitoring safety performance, reducing accidents, and making management decisions by the organization.

### 3. Results

#### 3.1. Data related to accidents and demographic characteristics of individuals

The number of people under study in an 8-year period (2004–2011) was 1,189, and a total of 287 cases of work-related accidents were recorded. The percentage of accidents occurred in men was 97.2 and that in women was 2.8. It should be noted that the ratio of the number of men (1,068 people) to women (121 people) employed at the power plant was 8.82. In addition, accident victims were mostly married (68.6%) and worked contractually or officially (75.6%) in the power plant. All accident victims in this work were aged above 20 years. The highest rate of accidents, i.e., 129 cases (44.9%) occurred in age group below 30 years, and the least number of accidents occurred in age group above 50 years. The number of accidents reduced with increasing working history so that the highest accident rate was in the group with working history below 5 years and the least accident rate was in the group with working history above 15 years. However, it should be noted that this trend was true for all years except for 2011, when the highest number of accidents was related to the group with working history of 5–15 years. The highest accident number was related to workers, with 57.2% (164 accidents), and the least accident number was related to managers, engineers, and experts, with 19.1% (55 accidents).

The highest accident number was related to the repair and maintenance unit with 35.2% (101 accidents), and the lowest accident number was related to the protection unit with 7% (20 accidents). The percentage of all employees in the repair and maintenance unit was 22.74. The most common accidents were trauma (30.7%), cuts (13.2%), and exposure to radiation, toxic, and nontoxic materials (12.5%). The most affected body organs were related to hand, such as arm, forearm, and fingers, with 125 accidents. The highest incidence of accidents occurred in winter, especially in March, and the lowest number of accidents occurred in August and September. The working cycle of the power plant was in two shifts, day (7 am–19 pm) and night (19 pm–7 am), with the highest incidence of accidents in the shift of day and at the beginning of the shift (7 am–13 pm) with 65.2% (187 accidents).

The results of Chi-square test suggested the significance of accident type at different months ( $p < 0.001$ ) and the nonsignificant

**Table 1**  
Interpretation of the safe T-score coefficient

Safe T-score coefficient	Interpretation
The standard deviation is between +3 and $-3$	There is no significant difference in AFR variation. The deviation is due to chance.
The standard deviation is greater than +3	Current AFR is significantly worse than the previous AFR.
Standard deviation is less than $-3$	Current AFR is significantly better than that before. The accidents have been significantly less reported.

AFR, accident frequency rate.

relationship between the accident type and time of accident occurrence (in terms of occurrence hours) ( $p < 0.001$ ). There was no significant relationship between the type of accident and working shift ( $p < 0.001$ ).

The most damaged organ was hand (hand, forearm, elbow, fingers, and wrist) with 43.6% (125 cases), followed by head and neck area (head, face, and neck) with 22.3% (17 cases). The results also showed that the main reasons for the occurrence of accidents in this 8-year period were unsafe actions (74%), unsafe conditions (16%), and not using personal protection means (10%). In addition, no significant relationship was observed between the reason of accident and working history of victim personnel ( $p < 0.001$ ).

### 3.2. Results of indices

Considering Table 2, the accident frequency index showed a totally descending trend from 2004 to 2011. The highest value of AFR and ASR was in 2004 (32.65) and 2008 (209), respectively, and the lowest value was in 2011 (9.75 and 29.26, respectively). The lowest number of accidents was in 2011, and the highest number of accidents was in 2009, while the highest number of personnel was also in 2009. According to Table 2, maximum lost working day was in 2008. Accident frequency–severity rate index, which is the interaction of severity and frequency indices, was highest (1.74) at the year before IMS implementation (2004), and it had the lowest value (0.56) in 2011. The results indicated that the relative frequency of accident number before IMS implementation was about 33% and that after the implementation of IMS was about 22%.

The minimum lost working time per accident was 1 day, and the maximum was 180 days. The minimum and maximum lost working days were related to 2004 and 2008, respectively. In addition, the severest accidents were related to accidents with vehicles, which led to losing 248 working days given the occurrence of four accidents. It should be noted that no accidents leading to death, permanent disability, or amputation occurred during the 8-year period in Yazd Combined Cycle Power Plant.

According to linear regression results, the AFR was reduced by increasing monthly income ( $p < 0.001$ ), and the frequency rate and frequency–severity index were reduced by increasing literacy level of personnel ( $p < 0.001$ ). Thus, monthly income and literacy level of personnel had a protective effect on these indices.

In addition, using personal protective equipment by workers in these years showed a growing trend. The lowest rate of using this equipment (15.2%) was in 2004, whereas the highest rate of using equipment (30.0%) was in 2011 among the accident victims (Table 2).

Fig. 1 indicates STS in different years. According to the figure and Table 1, no significant differences are observed in STS until 2008–2009 (changes result from chance), whereas this score reached to below  $-3$  in 2010–2011 and became significant (status was

improved, and safety and management plans were effective). The highest value of this score was in 2004 ( $-0.22$ ), and its lowest value was  $-3.19$  in 2011. In fact, the smaller the score is over the time (it gains more negative sign), the more the improvement of safety status it denotes. If this score is below 3, it means that the difference between the new and old frequency rate is statistically significant, and it is not by chance.

Given Table 3, which gives average indices in terms of working unit in years before and after IMS implementation, it is observed that the values of indices showed considerable reduction in 2004 (before IMS implementation) compared with that in years after implementation so that STS, which compares status before and after IMS implementation (considering Fig. 1), was significant in 2011 ( $STS < -3$ ). In fact, more negative index, especially smaller than  $-3$ , suggests that the impact of IMS and safety programs in the combined cycle power plant is more, and the tables support it too.

### 3.3. Prediction of indices after IMS implementation

Given the results obtained from other regression models, Cubic model or Grade 3 regression model was the best model for predicting indices of safety performance monitoring after IMS implementation in Yazd Combined Cycle Power Plant which was provided by the following formulas:

Variable X is the respective years after the IMS implementation. Regression results showed that the relation between all predictor variables ( $X^1$ ,  $X^2$ , and  $X^3$ ) with outcomes (indicators: AFR, ASR, and FSI) was significant ( $p < 0.05$ ), except for the variable  $X^1$  belonging to the ASR index. Given the above regression formulas, between the observed value due to analysis and the estimated value by Cubic regression, it is observed that values of all indices were at expected level, except for ASR index, and it results from safety performance improvement because of IMS implementation ( $p < 0.05$ ).

## 4. Discussion

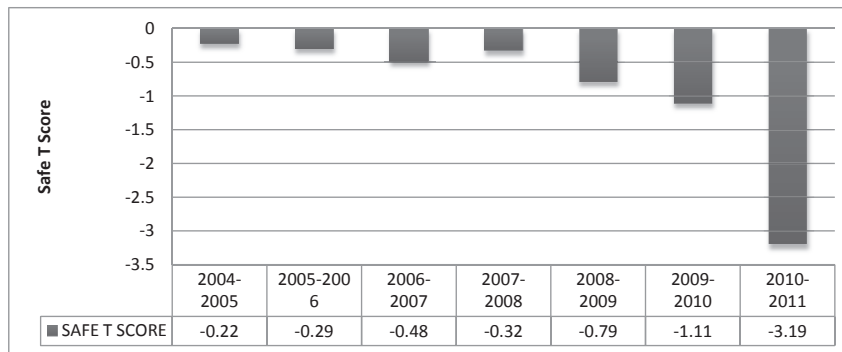
Recently, industrial and residential demands for electricity have increased seriously [23]. Because Yazd Combined Cycle Power Plant is located in one of the industrial provinces of Iran, the need for electricity in the region will be felt [24]. Therefore, considering the importance of Yazd Combined Cycle Power Plant in supplying urban and industrial electricity, conducting such studies will be of great importance in improving industrial performance indicators.

The findings of the present study showed that accidents are reduced by increasing age and working history, which is consistent with findings of Bylund and Björnstig [25], Cloutier [26], and Wadsworth et al [27]. The less experienced and trained personnel, curiosity, rush to carry out the activities, and lack of sufficient skills in using machines and equipment can be the causes. In fact, small

**Table 2**  
Accident indices in terms of different years in the combined cycle power plant

Year	Before IMS		After IMS					
	2004	2005	2006	2007	2008	2009	2010	2011
Number of accident	33	32	45	40	27	49	41	20
Lost workdays	92	97	122	101	232	135	73	60
Working hours (h)	196,000	204,000	300,000	288,000	222,000	420,000	418,000	410,000
AFR	32.65	31.37	30	27.77	26.12	23.33	19.61	9.75
ASR	93.78	95.09	81.33	70.13	209	64.28	34.92	29.26
FSI	1.74	1.72	1.56	1.39	2.33	1.22	0.82	0.56
Use of PPE n (%)	5 (15.2)	5 (15.6)	7 (15.6)	8 (20.0)	7 (25.9)	12 (24.5)	11 (26.8)	6 (30.0)

AFR, accident frequency rate; ASR, accident severity rate; FSI, frequency–severity index; IMS, integrated management system; PPE, personal protective equipment.



**Fig. 1.** Comparison of safe T-score in years before and after IMS implementation. IMS, integrated management system.

age and low working history, exacerbating the effects of each other, have a synergistic effect on the accident occurrence. As a result of this study, it is possible to identify high-risk occupational groups and consider necessary measures to switch high-risk jobs to lower-risk ones. The present study showed that the highest rate of accidents occurred in the repair and maintenance unit, which is consistent with findings of Cicek and Celik [28] and Pareek et al [29]. This requires serious attention to this working unit. Preventive maintenance can be used as an efficient management tool in this unit so that exposure to harmful risks and factors in these working environments are reduced.

The factors that increase the rate of unsafe actions in the married class can be related to the combination of mental and psychological stresses in work and family settings. Stress factors can be reduced by improving organizational communication, individual and group counseling, improving and modifying work environment, improving the safety status and ergonomics, and using relaxation techniques such as exercise.

In addition, the employment density of individuals in these hours of work and the lack of coordination and match of workers at the beginning of the shift can be pointed to as the factors contributing to the increase in accidents in the day shifts and at the beginning of the shift.

This study showed that the most observed type of accident was trauma and the most damaged organs were related to hand, such as forearm, elbow, and fingers of hand, which is consistent with the findings of Webb et al [30]. Hands are the most involved organs in activities of workers, which are more exposed to machinery risks than other organs; thus, the probability of damage and accidents for these organs is higher.

The results for accident reasons in this study were almost similar to those in the study by Heinrich on 75,000 accidents [31]. Heinrich found that 88% of accidents were due to unsafe actions, 10% were due to unsafe conditions, and 2% of accident reasons were unpreventable. If nonuse of personal protective equipment is regarded as an unsafe action, almost 90% of accident reasons in the power plant are unsafe actions, and 10% are unsafe conditions of working environments. Effective measures can be taken in this regard using engineering controls and ongoing training to eliminate unsafe conditions and actions.

The results of this study showed that safety situation in the years after implementation of IMSs (2005–2011) has improved compared with that in the year before the implementation of these systems (2004), and the greater the safety and the more detailed and orderly the management systems implemented are, the more dramatic the reduction in accident indices will be. The results of

**Table 3**  
Average indices in terms of working unit in years before and after IMS implementation

Year	Indices	Units						
		Repairs and maintenance	Chemistry and refinery	Vehicle and support	Exploitation	Technical and engineering	Protection	
Before IMS	2004	AFR	85.71	25.00	54.54	14.00	20.00	80.00
		ASR	278.57	75.00	172.72	30.00	40.00	180.00
		FSI	4.88	1.36	3.06	0.64	0.89	3.79
After IMS	2005	AFR	100.00	10.00	42.85	16.00	20.00	40.00
		ASR	269.23	10.00	121.42	62.00	30.00	200.00
		FSI	5.18	0.31	2.28	0.99	0.77	2.82
	2006	AFR	78.94	28.57	38.09	17.56	13.33	42.85
		ASR	236.84	64.28	90.47	47.29	26.66	142.85
		FSI	4.32	1.35	1.85	0.91	0.59	2.47
	2007	AFR	66.66	42.85	30.00	15.49	14.28	42.85
		ASR	188.80	114.28	90.00	33.80	35.71	57.14
		FSI	3.54	2.21	1.64	0.72	0.71	1.56
	2008	AFR	61.53	20.00	40.00	14.54	7.69	40.00
		ASR	130.76	50.00	1253.33	32.72	7.69	60.00
		FSI	2.83	1.00	7.08	0.68	0.24	1.54
	2009	AFR	80.76	21.05	46.42	5.71	7.69	50.00
		ASR	126.9	26.31	292.85	6.66	15.38	66.66
		FSI	3.20	0.74	3.68	0.19	0.34	1.82
	2010	AFR	57.69	25.00	17.85	11.53	7.69	40.00
		ASR	88.46	35.00	35.71	24.03	15.38	80.00
		FSI	2.25	0.93	0.79	0.52	0.34	1.78
	2011	AFR	20.00	15.00	14.28	5.88	0.98	20.00
		ASR	76.00	35.00	57.14	13.72	1.96	60.00
		FSI	1.23	0.72	0.90	0.28	0.04	1.09

AFR, accident frequency rate; ASR, accident severity rate; FSI, frequency–severity index; IMS, integrated management system; PPE, personal protective equipment.

this study were compared with the findings of other studies. They were completely consistent with the findings of Coleman and Kerkering [32] Goldenhar et al [33], Hamidi et al [16], Omidvari et al [9], and Fernández-Muñiz et al [17]. Coleman and Kerkering also considered the need for a professional safety and health program to assess the safety of miners and reduce the number of days lost [32]. Findings of Hamidi et al suggested the significance of different safety indices before and after the implementation of IMSs in cement industry [16]. In this study, the highest accident indices were related to the workers, and the least value of indices was related to engineers and experts, which was almost similar to findings of Hamidi et al [16], which reported the highest accident rate for miners. High accident rate among workers can be justified in a way that all construction, repair, and service activities are done by them and thus their exposure to harmful factors in working environments is high, which in turn leads to increased risk of exposure to risks. Omidvari et al [9] and Fernández-Muñiz et al [17] also achieved the positive impact of safety plans on accident indicators. The other finding in the present study was the significance of the STS during 2010–2011 although the trend of accident indices in the years before 2010 was descending. Findings of Goldenhar et al (2001) [33] showed that IMS would prove its effectiveness in long term (usually within 2–3 years). These systems, which are established for the prevention of accidents and maintenance of organizational resources, should be periodically monitored and evaluated; their weaknesses should be discovered, and corrective measures should be taken for elimination. Thus, their impact in this research during the years under study was gradual. A sudden increase was observed in the ASR due to the sudden accident in one of the power plant operators, which resulted in a loss of about 180 working days, and this index was increased suddenly because of the dependence on the lost working days.

The other finding in this work was the prediction and estimation of safety performance—monitoring indices in years after IMS implementation. After the investigation of different regression models, and given the significance of most of the coefficients in Cubic model, it was found that this model is the best one for predicting indices. Al-Ghamdi used logistic regression for predicting the effect of accident factors on accident severity and showed that logistic regression can be used as a suitable tool for improving safety in the future [34].

Therefore, the findings indicate that the implementation of safety programs and IMS systems has positive impact on the reduction of accident indices; thus, these indices provide a suitable tool for the management to monitor the performance of safety unit and control the role of management systems on accidents. In addition, no ethical limitation was observed in this work after required coordination. Absence of some damaged workers in workplace for interview and lack of accurate recording of the accident report form for damaged workers were among the limitations of this study. They were eliminated by providing necessary explanations about the study and its effective role in the prevention of similar accidents to damaged people or witnesses and respective authorities.

## 5. Future work

In this study, given that authors were not able to update information in the years after 2011, it is recommended that in future studies, for a better review, years after 2011 are also considered. It should be noted that during this period of time, factors such as the safety culture and the perceived risk of workers and personnel which may be affected by various factors such as media, management plans, and safety training which will be effective in improving the process should be considered in future studies. Meanwhile,

promoting awareness of people is one of the goals of IMSs, but it is better to focus on this issue.

## 6. Conclusion

The implementation of safety programs, especially that of IMSs, and their annual audits have had a significant impact on reducing accident indices and improving safety in this industry, within this period. Therefore, according to the results of this study, health and safety management systems are appropriate tools for reducing accident rate, and using regression models and accident indices is also a suitable way for monitoring safety performance in Yazd Combined Cycle Power Plant. In addition, using Cubic regression can be a suitable tool for evaluating the trend of indices and their prediction for planning and monitoring the performance of safety unit in this industry so that decision-making about the priority of safety programs in policies of organizations is facilitated. In addition, because today, risk evaluation results are used to offer corrective measures, the results of the epidemiology of accidents in this article can be documented in comprehensive database and can be used for quantifying risk evaluations. Finally, it should be noted that the implementation of IMSs in this industry has reduced accident indicators and it might have the potential to be applied to other plants.

## Conflict of interest

The authors declare no conflict of interest.

## Acknowledgments

This article is a part of the dissertation for the MSc program. Thus, the authors appreciate sincerely all those who collaborated in this study.

## Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.shaw.2018.04.001>.

## References

- [1] Kim Y, Park J, Park M. Creating a culture of prevention in occupational safety and health practice. *Saf Health Work* 2016;7:89–96.
- [2] Atombo C, Wu C, Tettehio EO, Nyamuame GY, Agbo AA. Safety and health perceptions in work-related transport activities in Ghanaian industries. *Saf Health Work* 2017;8:175–82.
- [3] Abad J, Lafuente E, Vilajosana J. An assessment of the OHSAS 18001 certification process: objective drivers and consequences on safety performance and labour productivity. *Saf Sci* 2013;60:47–56.
- [4] Flin R, Burns C, Mearns K, Yule S, Robertson E. Measuring safety climate in health care. *Qual Saf Health Care* 2006;15:109–15.
- [5] Takala J. Global estimates of fatal occupational accidents. *Epidemiology-Baltimore* 1999;10:640–6.
- [6] Jovanović JM, Arandelović M, Jovanović M. Multidisciplinary aspects of occupational accidents and injuries. *Facta Univ -Ser Work Living Environmental Protect* 2004;2(4):325–33.
- [7] Snashall D. Occupational health in the construction industry. *Scand J Work Environ Health* 2005;5–10.
- [8] Miller TR, Galbraith M. Estimating the costs of occupational injury in the United States. *Accid Anal Prev* 1995;27:741–7.
- [9] Omidvari M, Nourmoradi H, Davodi M. Effect of safety programs on occupational accidents and diseases indices in food industries of Ilam province over a 5-year period. *J Health* 2011;2:14–23.
- [10] Mariouryad P, Golbabaie F, Nasiri P, Mohammadfam I, Mariouryad H. Study of the continuous improvement trend for health, safety and environmental indicators, after establishment of integrated management system (IMS) in a pharmaceutical industry in Iran. *J Clin Diagn Res* 2015;9:LC18.
- [11] Graff B, Grenzmann C, Kladroba A, Stenke G, Berndt R, Griffith R, Grimpe C. ISO—international organization for standardization. Annual Report 2009. *ISO's Focus, Genf, H*; 2010.

- [12] De Oliveira OJ. Guidelines for the integration of certifiable management systems in industrial companies. *J Clean Prod* 2013;57:124–33.
- [13] Granerud RL, Rocha RS. Organisational learning and continuous improvement of health and safety in certified manufacturers. *Saf Sci* 2011;49:1030–9.
- [14] Duijm NJ, Fiévez C, Gerbec M, Hauptmanns U, Konstandinidou M. Management of health, safety and environment in process industry. *Saf Sci* 2008;46:908–20.
- [15] Bottani E, Monica L, Vignali G. Safety management systems: performance differences between adopters and non-adopters. *Saf Sci* 2009;47:155–62.
- [16] Hamidi N, Omidvari M, Meftahi M. The effect of integrated management system on safety and productivity indices: case study; Iranian cement industries. *Saf Sci* 2012;50:1180–9.
- [17] Fernández-Muñiz B, Montes-Peón JM, Vázquez-Ordás CJ. Relation between occupational safety management and firm performance. *Saf Sci* 2009;47:980–91.
- [18] Santos G, Barros S, Mendes F, Lopes N. The main benefits associated with health and safety management systems certification in Portuguese small and medium enterprises post quality management system certification. *Saf Sci* 2013;51:29–36.
- [19] Yazd power generation management company website. Retrieved September 12, 2017, Available from: <http://www.ypgmc.co.ir/SC.php?type=static&id=5>.
- [20] Pang R, Smith RW. Combined cycle power plant. Google Patents; 2016.
- [21] Konjkavemonefared A. The impact of individual factors on work-related accidents in Yazd and rankings based on Analytic Hierarchy Process. *J Ind Manage Sanandaj Islamic Azad Univ* 2012;18:13–25 [In Persian].
- [22] Velle JBR, Stephenson J. Safety training methods: practical solutions for the next millennium. John Wiley & Sons; 1995.
- [23] Al-Sulaiman Fahad A, Dincer Ibrahim, Hamdullahpur Feridun. Energy analysis of a trigeneration plant based on solid oxide fuel cell and organic Rankine cycle. *Int J Hydrogen Energy* 2010;35:5104e13.
- [24] Jozi AS, Pouriyeh AA. Health-safety and environmental risk assessment of power plants using multi criteria decision making method. *Chem Ind Chem Eng Q* 2011;17:437–49.
- [25] Bylund P-O, Björnstig U. Occupational injuries and their long term consequences among mechanics and construction metal workers. *Saf Sci* 1998;28:49–58.
- [26] Cloutier E. The effect of age on safety and work practices among domestic trash collectors in Quebec. *Saf Sci* 1994;17:291–308.
- [27] Wadsworth E, Simpson S, Moss S, Smith A. The Bristol Stress and Health Study: accidents, minor injuries and cognitive failures at work. *Occup Med* 2003;53:392–7.
- [28] Cicek K, Celik M. Application of failure modes and effects analysis to main engine crankcase explosion failure on-board ship. *Saf Sci* 2013;51:6–10.
- [29] Pareek PK, Nandikolmath TV, Gowda P. FMEA Implementation in a foundry in Bangalore to improve quality and reliability. *Int J Mech Eng Robot Res* 2012;1:81–7.
- [30] Webb G, Redman S, Sanson-Fisher R. Work injury experience at an industrial worksite. *J Occup Health Safe* 1992;8:143–53.
- [31] Brauer RL. Safety and health for engineers. 2nd ed. New Jersey (USA): Wiley-Interscience; 2006. 24 p.
- [32] Coleman PJ, Kerkering JC. Measuring mining safety with injury statistics: lost workdays as indicators of risk. *J Saf Res* 2007;38:523–33.
- [33] Goldenhar LM, Moran SK, Colligan M. Health and safety training in a sample of open-shop construction companies. *J Saf Res* 2001;32:237–52.
- [34] Al-Ghamdi AS. Using logistic regression to estimate the influence of accident factors on accident severity. *Accid Anal Prev* 2002;34:729–41.