ISSN: 2582-8118 ***Volume 1, Issue 4; July 2021***

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYSIS IN SCIENCE AND ENGINEERING

Web: https://www.iarj.in/index.php/ijrase/index

7. The View on Health and Safety in Industrial Engineering

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ABSTRACT

Safety management has entered a new era, one that is very different from the one in which it was first established. Safety engineering has grown rapidly in the last two decades in the United States, France, the United Kingdom, and Brazil. As the profession has grown, there has been an increase in the challenging of old ideas in both traditional and postindustrial labour. In high-risk industries including aviation, oil and gas, construction, transportation, steel production, and mining, ensuring worker and property safety is of paramount importance. Workplace injuries, illnesses, and deaths are all too common in these industries because of the risky conditions.

There are numerous dangers associated with industrial machinery. There are several rules, regulations, standards, and practises in place to ensure that machines are safe for people performing a variety of activities, such as operating and maintaining them. When activated, safeguards stop dangerous motion and protect workers.

As a result, just as quality is built into products and services, safety must be integrated into every work process in any industrial environment. Establishing and implementing an effective safety management system is essential in order to reduce the probability of reversible accidents.

Most individuals are aware of the most prevalent rules and regulations, yet only a small percentage actually follow them. There needs to be a particular aim for both owners and workers in order to improve the occupational health and safety (OHS) situation in industries. A lack of familiarity with laws, regulations, and moral obligations among employees and employers is a leading cause of workplace injuries and accidents. While the expense of promoting a safe, healthy, and productive work environment has an impact on production costs, the long-term profitability of a well-run business can't be overlooked.

KEYWORDS

Health, Safety, Industrial Engineering, VR, AR.

Introduction:

Competitive advantage is sought by businesses in order to survive in a globalised market. Having a well-trained workforce is a crucial consideration, since it encourages employees to work hard to improve their skills. We could lessen this effort by making sure that new hires' post-university skills are in line with what the market wants. Engineers (whether they are practitioners or managers) in the industrial sector are taking on more and more responsibility. Safety and health concerns in the workplace have increased over the past 30 years in order to foresee and prevent these kinds of difficulties.

Mobile equipment and walking personnel are common features of industrial work environments, which are dynamic in nature. The high number of workplace injuries and deaths is a clear indication of the dangerous working conditions seen in industrial facilities. These high-risk industries include construction, steel production, oil and gas, aviation, agriculture, forestry, fishing, and hunting, and so on. [1-3]

The emergence of Industry 4.0 has significantly altered our understanding of work systems in industrial safety. The fourth industrial revolution (so termed for this sort of industry) is the successor to the preceding three revolutions. Mechanization began the first industrial revolution in the 18th century, followed by the introduction of electricity and, finally, by the adoption of digitalization in the second and third revolutions. The Internet of Things (IoT), advances in smart use of digitalized information and technology, responsive devices in so-called "smart factories," and industrial automation via autonomous algorithms and artificial intelligence (AI) are the primary focus of the fourth industrial revolution (fourth IR) [4]. Traditional labour systems are being replaced by highly interconnected networks of people, technology, and business units in Industry 4.0. Mass customisation is becoming increasingly important as a means of staying competitive.

Although new legislation and standards have been enacted, the status and performance of occupational health and safety (OHS) remain open to a wide range of interpretations, which can be problematic.

Traditional thinking held that effective occupational health and safety (OHS) management is integral to any quality management system that aims to continuously improve the product or service. It was hoped that these systems would give a means of assessing gains gained through effective management of workplace risks, based on the Deming wheel or the PDMA technique. The benefits of installing an OHS management system are numerous, as it often improves communication channels as well as policies and procedures [5-7].

Among the most dangerous and unsafe industries, construction has a fatality and incidence rate significantly greater than the overall industry average in many nations. According to accident data, construction workers have a higher rate of fatal injuries than workers in any other sector. Though the construction industry has made strides to improve safety, it continues to have one of the highest per capita rates of on-the-job fatalities despite these efforts. Construction remains the most dangerous business in the United States in terms of the total number of deaths [8]. Thus, researchers and practitioners are constantly looking for new ways to strengthen management controls and human behaviour and the work environment in order to increase construction safety.

Having reliable control systems is essential if you want to keep people safe. The safety functions of interlocking guards and safety devices are strongly reliant on safe control systems (SF), and as risk increases, the reliability of the control system must increase as well.

Safety devices such as:

- interlocks,
- light curtains, multi-beam and single beam optical sensing devices, and laser scanners,
- safety mats,
- International standards are used to certify safety relays, safety modules, and safety programmable logic controllers (PLCs) (e.g., IEC 61496-1:2012 for electro-sensitive protective equipment).

Safety Performance Measurement:

In order to prevent accidents, it is important to measure safety performance in a work place and intervene to prevent risky behaviours and conditions.

Various safety performance metrics have been around for a long time and have proven helpful. OSHA's recordable injury rate (RIR), days away, restricted work, or transfer (DART) injury rate, or the experience modification rating on workers' compensation have typically been used to gauge safety performance in the United States.

Safety performance in the past was mostly assessed by relying on lagging indicators (such as incidents of accidents, illnesses, and fatalities), but a shift to utilising safety leading indicators to assess worker safety is now possible.[9]

As long as lagging indicators are still in use for predicting current and future safety performance, they have major drawbacks. A leading indicator of safety performance is therefore very important.

Emerging Technologies:

Safety training through computer-aided technologies:

Training workers in virtual reality (VR) and augmented reality (AR) and mixed reality (MR) has become a cost-effective and safe method of education. VR/AR/MR environments have also become increasingly popular in safety training to identify potential hazards and teach moving vehicle operators on the job site.[10]

Integrating BIM and safety:

Many studies and industrial applications have shown that safety and BIM integration can aid in safety planning and execution of projects, for example to automatic checking of construction models and schedules to prevent all-related accidents; automated scaffolding-related safety hazard identification, visualisation and prevention, blind spots identification and map-ping, path planning, near-miss information reporting and visualisation, etc.

Proximity detection devices:

Many proximity avoidance systems have been developed using various technologies, such as an ultrasonic-based sensor, radio-frequency identification (RFID) sensing technology, radar, GPS, and magnetic field generators, to prevent contact accidents, particularly for accidents caused by being struck by equipment.[11] In most cases, workers are warned when they are near heavy machinery by these technologies. Visual, vibratory, and aural warning signals are all examples of these types of warnings.

Wearable sensing devices:

Several industries, including healthcare, manufacturing, mining, and athletics, have implemented wearable gadgets. Devices that have proven effective and advantageous in these industries are being improved upon by both academic researchers as well as those in the businesses themselves. Many elite athletes utilise wearable sensors to monitor and measure their performance and safety. Sensors in NFL helmets detect concussions, smart compression shirts track arm movement, and approaches are used to evaluate a pitcher's effectiveness in Major League Baseball (MLB)

Objectives:

- As a part of this course, students will learn about a variety of topics related to industrial safety management.
- Methods for measuring safety performance that are currently in use and regularly utilised
- To improve industrial safety management, look at new technology in the vast majority of fields.
- To investigate the elements of safety training that can lead to better safety performance and outcomes when integrated into training programmes.

Review of Research:

Only a few publications have been written about OHS in Industry 4.0, according to Badri. OHS activities and technology breakthroughs by different manufacturers in Industry 4.0 are scattered, according to an assessment of the literature on Industry 4.0's technological advancements. To achieve a smooth transition to this new paradigm, scholars, field specialists, and industrialists must work together.

Virtual job analysis, dynamic occupational risk evaluation, cognitive analysis of workload, and skills management systems should be considered at the commencement of future OHS integration initiatives. Thirteen (p. 409)

Using IEC 61508 and EN 954-1 standards, Paques, et al. demonstrated a technical analysis utilised to support the safety assessment of an autonomous mining vehicle. Reliable safety control systems for the verification phase of zero electrical energy were designed by Poisson and colleagues. The programmable safety control system was designed and validated using ISO 13849-1 and 2 standards. It was determined that the performance level for an emergency halt should be calculated according to ISO 13849-1 by Zahálka et al. Functional safety control for the collaboration of press machines and operators is proposed by Hata and Hirao. A robot cell implementation of IEC 62061 is described in Jones.

There is a guide produced by the UK Health and Safety Executive (HSE) in 2003 to enhance understanding of the technical causes of control system failure. According to an investigation of occurrences, a systematic risk-based strategy may have prevented most of them.

According to Hillson and Murray-Webster and Breakwell, concepts concerning risk and even the word risk are "a source of substantial uncertainty even amongst people who specialise in the area." For example, Hopkins points out that the Longford catastrophe allegations against Esso may be based on a misunderstanding of the legal definition of "risk." There are three essential steps to risk management, according to Hopkins (p. 15), which are 'hazard identification, risk assessment and risk control.' However, the model established in ISO31000:2009 and its predecessors is at odds with these. "It is odd that we have no universal language for discussing the perils of life," Calman and Royston (p. 393) write. Health and Safety Executive (HSE) produced a guide in 2003 to enhance understanding of control system failures' underlying mechanisms. Presenting and analysing incidents that have been reported According to an investigation of occurrences, a systematic risk-based strategy may have prevented most of them.

Guard operated interlocking switches failed in four accidents, according to Villard. According to D'zwiarek, 144 machine-related incidents occurred in Poland between 1996 and 2002. It was determined that 54 of the incidents were caused by malfunctioning machine control systems. For the years 1990–2011, Chinniah looked at 106 accident reports involving stationary machinery in Quebec. Three accident investigations stated that the existing safety control system had been modified or bypassed.

Research Methodology:

It's important to point out that this is a hybrid method of bibliographic research, rather than a strictly systematic one. Indeed, the term "hybrid" refers to a mixture of multiple kinds of materials. It is possible to use the advantages of different research approaches in a hybrid or mixed methodology. It aids in gaining a thorough understanding of the subject matter being studied. The first step was to compile a list of readings by doing a thorough keyword search. The first step in our research was to conduct a search of the literature and choose relevant publications. The second thing we noticed was that numerous of the first publications we looked at led us to additional resources that were cited more than twice. These were incorporated within the review of the literature due to their importance. Third, in order to help readers better grasp the various terms and definitions linked to this study, such as OHS performance, performance measurement, and performance indicators, we have added relevant publications to the bibliography.

Result and Discussion:

An organization's ability to handle OHS effectively is viewed as a sign of OHS competence. Effective OHS management necessitates regular evaluation of performance in order to identify areas for improvement and gauge the impact of newly adopted measures. As a result, the tools employed in this evaluation must be dependable and not become a burden, resulting in irregular evaluation [12]. Evaluation tools that use both reactive and proactive indicators, as well as mixtures of the two, are described in the scientific literature. It is possible that this combination will give an overall picture of OHS performance and, as a result, help to direct the development of more effective measures. Table 1 summarises the advantages and disadvantages of both types of indicators.

Type	Advantages	Drawbacks
Reactive	- Simple, straightforward - Inexpensive - Rapid - Easy to interpret - Outline actual OHS status	- Unreliable - Low sensitivity - Focused on past performance - Depend on injury / illness reports - Underestimate risk of illness
Proactive	- Describe current performance - Relate to specific objectives - Suggest preventive actions	- Evaluation validity depends on the choice of indicators - Difficult to measure objectively

Table 1. Advantages and drawbacks of proactive and reactive indicators of OHS status

Safety data collection:

Safety event data includes both leading and lagging indicators (e.g., near misses) (injures, illnesses, fatalities). Across high-risk industries, near-miss and incident reporting procedures have been advocated and established. According to OSHA regulations (Standards—29 CFR 1904):

- OSHA requires businesses to report all work-related fatalities and severe injuries.
- In the event of a work-related death, hospitalisation, amputation, or loss of sight, employers are required to notify OSHA.
- It is required to report a fatality within 8 hours.

- In-patient hospitalisation, amputation, or sight loss must be reported within 24 hours of their occurrence.

Safety data analysis:

According to OSHA, the incidence rates represent the number of injuries and illnesses per 100 full-time workers and are calculated as (N/EH) × 200,000:

$$\text{Incident rate} = \frac{(\#\text{of cases or days } per \text{ year}) \times 200{,}000}{\text{Total employee hours } per \text{year}}$$

EH is the total number of hours worked by all employees in the calendar year; 200,000 is the base for 100 equivalent full-time employees (working 40hours per week, 50weeks per year). There is a wide range of information available through the US BLS Injuries, Illnesses, and Fatalities (IIF) programme [13-15]. Occupational injuries and illnesses (SOII) and fatal occupational injuries (Census of Fatal Occupational Injuries) are collected and reported annually (CFOI).

The study's findings are consistent with the approach, which began with an examination of traditional safety procedures and the advancements in theoretical safety science and how these improvements meet the difficulties of Industry 4.0. Training programmes now include a number of new features aimed at improving both the learning experience and outcomes for employees. Table 2 provides a concise summary of the various aspects of safety training, as well as the most important advantages [16]. By deliberately including these factors into the design of safety training programmes, it is possible to increase the impact and benefit from the lessons learned. The industry has been searching for decades for a way to improve safety, and a unified approach with the adoption of such training aspects just might be the answer.

Safety Training Elements	Key Benefits
Visual Cues, Mental Schemas, and Energy-Based Mnemonics	-Guides workers to systematically examine workplaces to enhance hazard recognition levels
Training in Virtual Reality / Augmented Reality / Immersive Environments	-Offers a safe environment for demonstrating high-risk workplace conditions that cannot be replicated in real workplaces
	-Associated with high engagement levels and immersive experiences
Multimedia Presentations including Animations, Videos, and Photographs	-Developed resources can be reused in a cost-effective manner
	-Is being integrated into online education and training modules that are widely distributed
	-Useful in packaging essential safety information in an engaging manner

Safety Training Elements	Key Benefits
Testing and Feedback	-Evaluate current skill level and offers clarity on what good performance looks like
Leveraging Eye-Tracking Technology and	-Highlights weaknesses associated with hazard recognition abilities
Visual Attention Maps	-Offers the capability of providing feedback and self-assessment
Metacognitive Prompts	-Guides trainees to self-assess weaknesses and adopt remedial efforts
	-Simple schematic representation of safety control measures
Hierarchy of Controls	-Guides trainees to prioritize safety control measures based on relative effectiveness to minimize safety risks
Hands-on and Active Training Approaches	-Associated with superior engagement levels and training outcomes
On-the-job Training and Apprenticeship	-Offers suitable context and realistic environment for training activities
programs	Trainees are more likely to replicate learned concepts at the workplace
Integration of Training Transfer Elements	-Ensures that learned concepts from training are adopted in the workplace
Andragogy-based Training	-Better suited for adult workers and promotes collaborative learning
Naturalistic Injury Simulations and Physical Demonstrations	-Offers the capability of communicating safety information in a realistic and tangible manner
Serious Games and Gamification of Safety Training	-Promotes learning using an engaging experience
Personalized and Adaptive Training	-Tailors learning experiences in accordance to the training needs of trainees
	-Eliminates repetitive and unnecessary training in areas trainees are already proficient
	-Offers the ability to train large number of trainees in a cost-effective manner
E-learning or Online-based Training	-Trainees may be able to access training material on an on-demand basis
Focus-Four Hazards Training	-Targets safety hazards that are responsible for a disproportionate number of fatalities effectively
Peer-led or Initiated Training	-Empower trainees to learn from each other in a friendly and safe setting
Practice-based training and Guided practice sessions	-Allows trainees to learn safety information using a trial and error approach
Social and collaborative Learning Experiences	-Promotes mutual learning through observations, interaction, and emulation.

Table 2. Summary of safety training elements along with key benefits.

Safety-related control systems linked with machinery are governed by two international standards, ISO 13849 and IEC 62061 [17-19]. When it comes to designing machinery safety safeguards, safety experts and machine designers look to those standards as the pinnacle of the field. There are two distinct levels of discrete reliability: ISO's "Performance level" (PL) and IEC's "Safety integrity level (SIL). This graphic compares the likelihood of a dangerous failure per hour for PL against the probability of a dangerous failure for SIL.

Parameters for Risk Estimation:

Additionally, ISO 13849 and IEC 62061 provide additional recommendations on the design of equipment safety control systems in ISO 12100. According to this definition, risk is defined as a sum total of the chance of injury (Table 3) and the intensity of harm (Tables 5 and 6) [20]. For machinery safety, this notion of risk is widely accepted. Using all or some of the ISO 12100 characteristics, ISO 13849 and IEC 62061 relate to this concept of risk when specifying the appropriate performance level and safety integrity level (Table 5).

	ISO 12100	ISO 13849	IEC 62061
	Severity of harm	Severity of injury	Severity of harm
Probability of occurrence of harm	Exposure of persons to hazards	Frequency and/or exposure to hazard	Frequency and duration of exposure
	Occurrence of hazardous events	Not mentioned	Probability of occurrence of a hazardous event*
	Possibilities of avoiding or limiting harm	Possibility of avoiding the hazard	Probability of avoiding or limiting harm

Table 3. Parameters used for risk estimation in three fundamental standards.

Probability of Occurrence of Harm		
Exposure of Person to the Hazard	**Occurrence of a Hazardous Event**	**Technical and Human Possibilities to Avoid or Limit Harm**
Need for access to the hazard zone	Reliability	Persons are skilled or unskilled
Nature of access	Accident history	Speed in a hazardous situation leads to harm
Number of persons requiring access	History of damage to health	• Suddenly • Quickly • Slowly
Frequency of access	Comparison of risks	Awareness of risk
		• Direct observation • Warning signs • Information for use

Probability of Occurrence of Harm		
Exposure of Person to the Hazard	**Occurrence of a Hazardous Event**	**Technical and Human Possibilities to Avoid or Limit Harm**
		Ability to avoid or limit harm
		• Reflex • Agility • Possible escape
		Practical experience and knowledge
		• Of the machinery • Of similar machinery • No experience

Table 4. Factors affecting the three parameters defining the probability of occurrence of harm based on ISO 12100.

Severity of Harm	
Severity of injuries or damage to health	**Extent of harm**
• Slight • Serious • Death	• One person • Several persons

Table 5. Factors affecting the severity of harm based on ISO 12100.

Levels of The Parameters According to…		
Parameters of risk	**ISO 13849-1:2015**	**IEC 62061:2005**
Severity of harm	S1-slight (normally reversible injury) S2-serious (normally irreversible injury or death)	Reversible: requiring first aid; se = 1 Reversible: requiring attention from a medical practitioner; Se = 2 Irreversible: broken limb(s), losing a finger; Se = 3. Irreversible: death, losing an eye or arm; Se = 4

Levels of The Parameters According to…		
Parameters of risk	**ISO 13849-1:2015**	**IEC 62061:2005**
Exposure of the persons to hazards	F1 – Seldom-to-less-often and/or exposure time is short F2 – Frequent-to-continuous and/or exposure time is long	≤ 1 h: Fr = 5 > 1 h to ≤ 1 day: Fr = 5 > 1 day to ≤ 2 weeks: Fr = 4 > 2 weeks to ≤ 1 year: Fr = 3 > 1 year: Fr = 2
Occurrence of hazardous event	The probability of avoiding the hazard and the probability of occurrence of a hazardous event (Pe) are both combined in the parameter P. The probability of occurrence of a hazardous event is assumed to be 100% the worst-case scenario. Where the probability of occurrence of a hazardous event can be justified as low, the PL may be reduced by one level.	Very high: Pr = 5 Likely: Pr = 4 Possible: Pr = 3 Rarely: Pr =2
Possibility of avoiding or limiting harm	P1– Possible under specific conditions P2– Scarcely possible	Impossible: Av = 5 Possible: Av = 3 Probable: Av = 1

Table 6. Comparison between ISO 13849-1:2015 and IEC 62061:2005 relative to parameters of risk.

Conclusion:

For a better working environment, new site owners and managers should implement some modern practises or OHS provisions. Everyone must immediately grasp new concepts and ideas if we are to achieve a consistently high standard of performance. Because today's workforce will be more efficient and professional in the future because of today's introduction of the OHS idea. The cost of labour is increasing exponentially over the world.

Despite the fact that it is still relatively inexpensive in our country, this will soon change. Consequently, by adopting the truth and in order to compete in the global market, the owners should step forward to be updated on the OHS sector. Whether it's making the interactions in a system transparent or focusing on specific safety issues that can be addressed with appropriate resources, complex safety difficulties will need to be assessed. To better understand work system performance variability, some of the advancements in Industry 4.0 can be applied. Process industries will benefit from the complexity-thinking methodologies that are currently used primarily in academic settings. The ability to transition between micro, meso, and macro understandings of systems, which supports the use of hybrid approaches at various levels of abstraction from systems and their subsystems, will become increasingly important in controlling risk. An effective countermeasure against cherry-picking methods is to disentangle the current overlaps between hazard identification, risk assessment, injury models and management methodologies and risk mitigation.

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