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A STUDY ON THE IMPACT OF POTENTIAL MACHINE SAFETY FACTORS IN ACHIEVING ACCIDENT-FREE WORKPLACE

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ABSTRACT

Background: The study was conducted in an automotive spare part manufacturing industry located in South India. The various machinery safety factors were identified and studied in selected work stations. **Aim:** This study was initiated to identify the critical factors and to design a Structural Equation Model to find the resultant effects and the degree of relationship among the predominant machine safety factors. **Materials and Methods:** Systematic random sampling method was adopted to collect 142 samples. Twenty Five variables influencing Safety Factors were identified in the questionnaire, validated and responded in Likert type five-point scale. **Statistical Analysis:** Factor analysis was done to extract the predominant factors and seven iterations were extracted. Structural Equation Model (AMOS 20) was used for the analysis to find the resultant effects and the degree of relationship among the seven factors. The data was analyzed by the IBM-SPSS version-20. Demographic study, Descriptive Statistics, fitting the models using AMOS Graphic was performed. **Results:** The factor analysis revealed that seven predominant factors. SEM model analysis is done based on model fitness indices (goodness of fit). **Conclusions and Implications:** The result of the Fit statistics of the structural model confirms the Model is fully supported and found FIT. Construct validity has been achieved during GFI, NFI and CFI being nearest to 0.90 and the RMSEA is 0.000. Internal reliability has been achieved with the Cronbach's Alpha value of 0.752. It is concluded that there is a significant level of association among the machinery safety factors.

Key Words:
Predominant Machinery Safety factors
Human-Machine Interface
Training
Hazards
Risks
PPE

1.0: Introduction

Occupational safety is a concern for many companies worldwide. It contributes not only to protect the most important asset of companies, workers, but also to increase productivity and efficiency. Despite the fact that companies are primarily seeking to eliminate accidents, especially those leading to workers' injuries, it is generally accepted that occupational accident prevention is also achieved by reducing the number of minor incidents that occur in a workplace.

Safety should always be the main concern in a facility with production technology. Appropriate safety measures help to ensure that your employees are safer, and it's simply a smart business practice. Shutting down a machine, factory or jobsite to address a safety incident can be costly in terms of lost work-time, lost-revenue, as well as possible insurance issues. Safety incidents can also cause added obstacles in terms of reports, audits, or legal issues.

Machinery with moving parts and workers who operate them has an uneasy relationship. Machinery makes employees more productive and enable them to form and shape material in ways that would be impossible with hand-tools. Technology can make machines safer, but as long as employees need equipment to help them process material – to cut, shear, punch, bend, or drill – they will be exposed to moving parts that could harm them. Much of the hazard occurs at the point of operation, where the work is performed and where the device cuts, shears, punches, bends, or drills.

Due to advanced computer techniques available on the market there is an increasing number of accidents at work which are caused by unpredictable functioning of machine control systems. Inappropriate functioning of machine control systems results in an improper operation of a machine, which may consist in, e.g., altering the parameters of working motion or unseemly signaling of the machine working state. As a result, the requirements of production quality will not be satisfied or defective elements will be formed, which will undeniably involve adding production costs. Much more risky, however, are possible erratic movements of the machine as well as involuntary speed changes, unexpected starts or no stops when there should be one, ejection of mobile elements or machined parts, etc. Such phenomena appear when improper functioning of machine control systems causes loss of safety function responsible for preventing effects like that. Such behaviour of the device may cause an accident at work involving much more serious results, leading to the loss of health or even life of the worker. Therefore, this study aims at determining typical phenomena causing accidents of this type.

2.0: Objectives

1. To study the demographic profile of the respondents on machine safety factors in industry.
2. To analyze the primary data for the structural equation modeling on the potential machine safety factors in industry.

3.0: Review of Literature

Although the total numbers of mine worker fatalities in the United States, as well as fatality incidence rates, have trended downward during the past 20 years, the proportion of these accidents involving mine and mobile equipment has constantly been significant (Kecojevic, Komljenovic, Groves, & Radomsky, 2007). Researchers at the National Institute for Occupational Safety and Health (NIOSH) have been concerned with the interaction of workers and machinery and with the number of severe accidents classified as struck-by or caught-in (Burgess-Limerick & Steiner, 2006a; Ruff, 2007; Schiffbauer, 2005; Venem, Shutske, & Gilbert, 2006). These accidents include employees entwined in revolving equipment, struck by moving machine components or run over by mobile equipment. An analysis of accident data available from the Mine Safety and Health Administration (MSHA) was conducted to better understand the problem and scope of machinery-related accidents.

Prevailing accident theories emphasize the role of the organization in accident prevention, instead of attributing blame to the victim in the case of an accident. This approach is supported by the finding (Reason, 1997) that a significant number of major accidents have their origins in management and technical structures. Such causal factors include inadequate supervision and instruction, established unsafe work practices, and poor workplace design. These factors have generally existed long before the occurrence of an accident. However, in the event of an accident, a local trigger such as human error compounds the danger of latent accident sources (Becker 1997; Reason, 1997; Wickens & Hollands, 2000).

Learning from accidents to prevent further occurrence should concern the whole organization. However, learning from accidents and utilizing accident information appears to be a complicated issue (see e.g. Baram, 1997; Becker, 1997; Koornneef & Hale, 1997).

Industrial maintenance presents several challenges for accident prevention. In addition to the usual risks associated with any industrial working environment, maintenance operations involve several maintenance-specific risks. Typical of these include working alongside a running process, using complicated machinery, and time constraints (Reason & Hobbs, 2003). In contrast to many other areas of technology and industry, direct contact between operator and machine in maintenance activities cannot be reduced substantially. Distancing people from processes typically diminishes the likelihood of human error and other chains of events that can lead to accidents. However, maintenance is, and probably will remain, an area in the use of technology where humans need to be in direct contact with processes (Reason, 1997). Maintenance is also a good example of work that is performed in exceptional conditions, such as the time of day, especially when high-priority repairs are involved (c.f. Nag & Patel, 1998).

A maintenance operation may also be exceptional work in itself depending on the frequency it is performed. The current increasing practice of subcontracting maintenance services may also pose new challenges as the sites and tasks can vary according to the customer environment. In addition, maintenance operations typically include both disassembly and reassembly, which can be considered factors in increasing the risks of injury. Further, the numerous work phases during disassembly and reassembly can give rise to greater risk of human error (see e.g. Herrera et al., 2008; Hobbs & Williamson, 2002; Reason, 1997; Reason & Hobbs, 2003). Such errors include replacing a wrong part or assembling the right parts in the wrong order. Because of human error, maintenance activities can diminish the reliability of a technical system. However, maintenance activities also have features that make them risky for the maintenance workers.

4.0: Materials and Methods

A questionnaire is developed in line with previous research studies. Twenty five components (variables) influencing machinery safety were identified, validated and then measured by applying Likert type scale. The respondents are required to give their responses on a five-point scales ranging from strongly agree to strongly disagree. The Primary data were collected from 142 respondents of varying categories such as contract workmen, trainee/Apprentice, operator, supervisor and manager using random sampling method. Data was analyzed by applying various statistical techniques like descriptive statistics, Pearson's correlation and factor analysis using SPSS version 20 for Windows. Thereafter, AMOS 20 has been utilized to derive a model which establishes the inclusive relationship among the variables of the study and the data is analyzed in several steps for the model fit.

5.0: Results and Discussions

The results identified and extracted the seven predominant potential machinery safety components in the manufacturing industry. And also, it shows that the significant relationship among the machinery safety components. It has been found that there is a high significance among the extracted and identified seven machinery safety components. Table-1 shows the demographic profile of the respondents under study.

Table 1 Demographic Profile of the respondents

Variables	Elements	Frequency	Percent
Gender	Male	116	81.70
	Female	26	18.30
	Total	**142**	**100**
Age	Below 20 years	30	21.10
	20-30 years	45	31.70
	30-40 years	50	35.20
	40-50 years	17	12.00
	Total	**142**	**100**
Marital Status	Single	26	18.30
	Married	112	78.90
	Separated	4	2.80
	Total	**142**	**100**
Education	Below 5th	7	4.90
	6th – 10th	44	31.00
	Diploma/PUC	76	53.50
	Degree	15	10.60
	Total	**142**	**100**
Grade	Contract	32	22.50
	Trainee/Apprentice	110	77.50
	Total	**142**	**100**
Years of Experience	5-10 years	78	54.90
	10-15 years	38	26.80
	15 - 20 years	26	18.30
	Total	**142**	**100**
Hours worked per week	41 - 50 hrs	106	74.60
	51 - 60 hrs	36	25.40
	Total	**142**	**100**

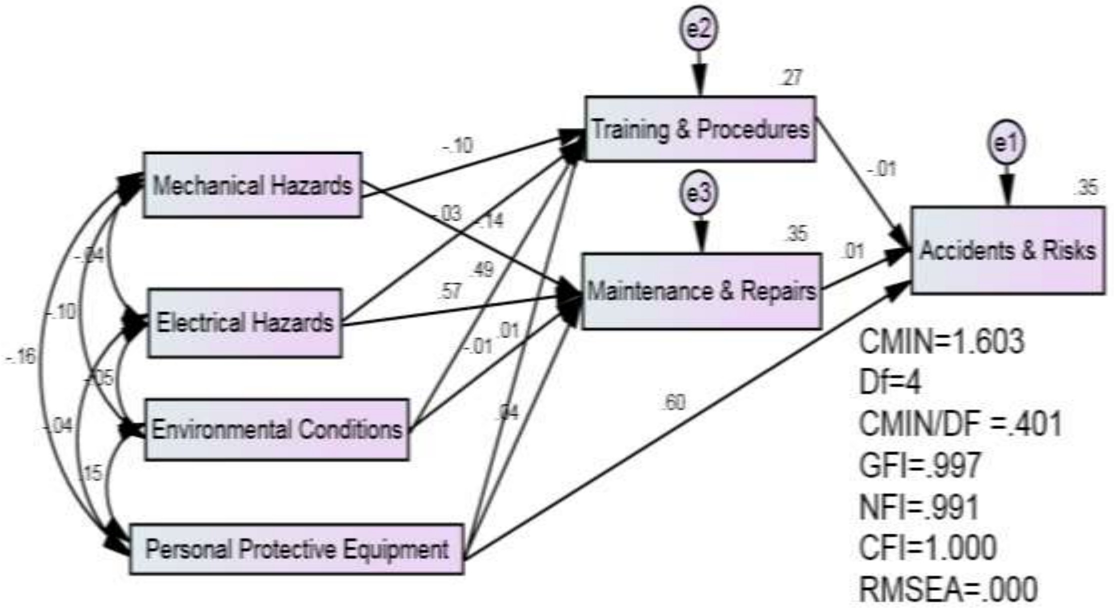
The demographic profile of the majority of respondents in Table.1 shows that 81.70 percent of the respondents are Male and the 35.20 percent of the age group are in 30-40 years age group, 78.90 percent of the Marital status are in married respondents, Educational qualification of the respondents shows that 53.50 percent are in the Diploma/PUC group, 54.90 percent of the respondents are having more than 5-10 years of experience. 77.50 percent of respondent's grade is trainee/apprentice and 74.60 percent are working for 41-50 hours per week.

Table.2 Descriptive Statistics for Factors in Potential Machine Safety

Factors	Number of variables	Mean	Std. Deviation
Mechanical Hazards	4	13.768	4.289
Environmental Conditions	4	14.423	3.825
Training & Procedures	4	14.113	4.018
Accidents & Risks	4	14.542	3.974
Electrical Hazards	3	11.697	2.535
Personal Protective Equipment	3	11.500	2.644
Maintenance & Repairs	3	11.528	2.540

Table 2 shows the descriptive statistics for the factors in potential machine safety and it shows that mean, standard deviation measures are high internal reliabilities with correlation ranging from -0.134 to 0.595 (Swaminathan GS, 2020). The Pearson's correlation test shows that there exists a high positive correlation among Accidents & Risks and PPE, Maintenance & Repairs and Environmental Concerns, Training & Procedures and Electrical Hazards, and a negative correlation exist among Training & Procedures and Mechanical Hazards (Swaminathan GS, 2020).

Figure: 1 Standardized Estimates



5.1: Fitting the Models Using AMOS Graphic

The researcher should take benefit from the results of preceding researches by identifying limitations on a positive parameter in the model. Researchers preserve fit multiple models in a single analysis. AMOS Graphic observes each pair of the models, where one representation can be obtained by placing parameter limitations on the other. AMOS could also identify the pair of redundant items in a dimension model that put at risk the fitness of the model. The researcher can either limit a pair of unused items in a measurement model, or delete the item altogether from the model in order to improve the fitness of the model in future.

Table.3 Measurement Model for the Validity

Items	CR	AVE	MSV	Max R(H)	MH	PPE	EC	EH
MH	0.030	0.015	0.026	0.030	**0.124**			
PPE	0.134	0.119	0.026	0.355	-0.160	**0.344**		
EC	0.119	0.122	0.023	0.243	-0.104	0.152	**0.349**	
EH	0.145	0.161	0.003	0.321	-0.044	-0.041	-0.050	**0.401**

5.2: Validity Concerns

- Discriminant Validity: the square root of the AVE for MH is less than one the absolute value of the correlations with another factor.
- Reliability: the CR for MH is less than 0.70.
- Convergent Validity: the AVE for MH is less than 0.50.
- Discriminant Validity: the AVE for MH is less than the MSV.
- Reliability: the CR for PPE is less than 0.70.
- Convergent Validity: the AVE for PPE is less than 0.50.
- Reliability: the CR for EC is less than 0.70.
- Convergent Validity: the CR for EC is less than the AVE.
- Convergent Validity: the AVE for EC is less than 0.50.
- Reliability: the CR for EH is less than 0.70.
- Convergent Validity: the CR for EH is less than the AVE.
- Convergent Validity: the AVE for EH is less than 0.50.

5.3: Structural Model

SEM model analysis result based on model fitness indices (goodness of fit) shown in Table 4. These index values would be compared with critical value (cut-off value) of each index. A good model was expected to have larger or equal goodness of fit indices to critical value.

Table.4 Fit Statistics of the Structural Model

Fit statistics	Recommended Value	Values	Interpretation	Inference
Chi-square χ2	-	1.603	Compares obtained *x*2 value with tabled value for given *df*	Supported
Degrees Freedom df	-	4		
Chi-square/Degrees Freedom χ2 /df	Carmines and McIver, 1981, page 80	0.401	Reasonable fit	Supported
goodness of fit GFI	Tanaka and Huba (1985).	0.997	Value close to 0.90 or 0.95 reflect a good fit	Supported
The Normed Fit Index (NFI)	(Bentler & Bonett, 1980)	0.991	Value close to 0.90 or 0.95 reflects a good model fit	Supported
Comparative Fit Index (CFI)	Bentler, 1990)	1.000	Value close to 0.90 or 0.95 reflects a good model fit	Supported
Root Mean Square Error of Approximation (RMSEA)	Steiger and Lind (1980)	0.000	Value of 0.05 to 0.08 indicate	Supported
Standardized RMR	Square root SRMR (<0.08)	0.014	Value less than 0.05 indicates a good model fit	Supported

From the table 4 it is observed that the indices fitted to the models perfectly with approximate fit indices being nearest to 1.000. The RMSEA value of 0.000 is found supported. For both the order SEM model has been achieved since the measuring items have acceptable factor loadings which are greater than 0.50 for their respective latent constructs. Construct validity has been achieved during GFI, NFI and CFI being nearest to 0.90 and the RMSEA is 0.000. Internal reliability has been achieved with the Cronbach's Alpha value of 0.752 for the 25 variables.

6.0: Conclusions

Machine safety factor is an important issue in operation management in a manufacturing industry. This study focused primarily on analyzing machine safety factors by accidents and risks across disciplines while controlling for a variety of demographic and professional variables. Machine safety factors were also shown to be affected greatly by operational factors, such as design, maintenance, work load etc. Analyzing machine safety factors across various machines can help production, operation, maintenance, HSE teams to identify factors that contribute to the accidents and risks in the industry.

In a broader sense, the study also revealed that machine safety factor is not only related to how it is designed with advanced technologies, but also how the operational features are well understood, suitably handled and maintained at the workplace. The analysis also reveals that four factors namely mechanical hazards, electrical hazards, environmental concerns and personal protective equipment are the leading factors along with the mediating factors such as training & procedures and maintenance & repairs leading to accidents & risks at the workplace in an industry.

The result of correlation analysis also confirms the positive correlation among the predominant factors. In a manufacturing industry, the operation management has to consider the above seven factors and focus more on Occupational Health, Safety & Environment policies and practices suitably and create a conducive, safe work environment to the working population to improve their performance.

Further studies may focus on larger samples of machines and industrial segments to get a better picture for taking policy and procedural compliances to HSE concerns and decisions at the national level. It is also recommended further to focus on operation and machine wise studies to understand various factors influencing the machinery safety in various sectors.

Conflicts Of Interest

Author does not have any conflicts of interest to declare.

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References

[1]. Burgess-Limerick R, et al. Analysis of injuries highlights high priority hazards associated with underground coal mining equipment. American Long wall Magazine 2006; 19–20.

[2]. Kavianian HR, *et al*. Occupational and Environmental Safety Engineering and Management. Van Nostrand Reinhold, New York. 1990.

[3]. Kecojevic V, *et al*. An analysis of equipment-related fatal accidents in U.S. mining operations: Safety Science : 2007; 45, 864–874.

[4]. Kecojevic V, *et al*. The causes and control of loader- and truck-related fatalities in surface mining operations. Intl. J. Injury Control and Safety Promotion: 2004; 11(4), 239–251.

[5]. Raouf A, *et al*. Safety Assessment Quantitative Approach. Lewis Publishers, London. 1994; 11 - 14.

[6]. Reason J, A systems approach to organizational error. Ergonomics 1995; 38 (8): 1708-1721.

[7]. Reason J, Human error. Cambridge University Press. Cambridge; 1990.

[8]. Ruff T, Evaluation of a radar-based proximity warning system for off-highway dump trucks. Accident Analysis and Prevention, 2006; 38: 92–98.

[9]. Schiffbauer W, An active proximity warning system for surface and underground mining applications. Proceedings of Long wall USA international exhibition and conference. Pittsburgh, PA. 2005.

[10]Venem M, *et al*. Testing and creation of a safety system to disengage the PTO of a tractor. Applied Engineering in Agriculture, 2006; 22(1), 5–12.