An Empirical Analysis of a Process Industry to Explore the Accident Causation Factors: A Case Study of a Textile Mill in Pakistan

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Abstract: Industrial revolutions not only improved the general lifestyle of individuals but also brought an increase in the diversity of the manufactured goods. This diversification involved use of advanced technology and complex methods that entailed dangerous conditions. According to international labor organization, occupational accidents cause death of more than two million individuals each year in different industries. Process industries are complex in nature and tend to lead to more accidents. In Pakistan among the process industries, textile mills are the most accident prone industries in recent times. Therefore, an empirical analysis of a textile process industry has been done using structural equation modelling to examine the interactions between the contributory factors of accidents. Results revealed that unsafe acts are a major contributor to human error, equipment error and unsafe environment that in turn lead to the calamities and disasters that can be avoided with proper safety measures in place.

Keywords: Empirical analysis, Accident causation, Process industries, Structural equation modelling, Industrial Safety.

1. INTRODUCTION

Increase in the human population led to the foundation of more and more industries to meet their demands. These industries include the construction industry, automotive industry, defense and aerospace industry, agriculture industry, mining industry, forestry industry, quarrying industry, fish industry and the process industry. Process industries are the industries that involve operations of composing, reacting, blending or splitting to enhance the value of the material. An industrial site at which refurbishment of items, products and merchandise takes place is known as a process plant. Processes may vary from blending, splitting, packaging, converting to altering the raw material without producing completely new fabricated objects. These processes are such that once the output product is manufactured it cannot be disassembled back into its raw form. Food processing plants, wood processing plants, chemical plants, petrochemical plants, concrete plants, cement plants, steel plants, textile mills, pharmaceutical plants, paper processing plants, oil & gas refineries, offshore oil and gas plants, all constitute the process plants.

Accidents in industries have diverse effects. They lead to absenteeism, scarcity of experienced and reliable staff and permanent damages to the individuals both physically and psychologically which directly effects the industry's performance and the economy of the country as a result. It has been stated that owing to these accidents, 4% of the total GDP is lost globally every year accidents [1]. According to Pakistan Economic Survey 2015-16, there are 57.42 million employed people [2], out of which 4% are involved in the occurrence of accidents in different industries [3]. These accidents occur due to various reasons and to find the causes, plenty of techniques have been used but they don't address the interdependency of these causation factors. For that purpose structural equation modelling has been used in this study to explore the contributory factors that lead to accidents [4].

2. LITERATURE REVIEW

As the causes of accidents are not single or simple, plenty of accident causation analysis techniques have been developed and applied across various domains. However, there is a shortcoming in models that predict the causes of accidents and deal with the complex nature of causation [5]. Also, it has been clearly observed that textile industry is the most hazardous and accident prone process industry in Pakistan in recent times. Therefore in this study a structural equation modelling approach has been used to analyze the accident causation in a textile process industry which not only determines the main contributory factors but also proposes a model which will help the industries in maintaining a safe environment and help attain the zero accident vision.

2.1. Latent Variables and Measurement Components

The literature reveals that accidents occur mainly due to the unsafe acts, equipment error, human error

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and the unsafe environment. Each of these constructs has its own observable variables.

2.1.1. Unsafe Acts

Unsafe acts are the acts that are done in the presence of a major hazard [6]. They are the steps that, if not taken at the time of need, can cause a major harm to the safety of the plant [7]. Before 1930's unsafe conditions, which are the hazards already present in the system that can lead to an accident, were considered to be the main culprits. The term 'unsafe acts' has been first coined in 1930 [8], and since then it has been considered as the first and foremost reason of occurrence of accidents [9]. Reynard and Billings have concluded that the prime reason of 70% to 90% accidents are the unsafe acts [10]. Unsafe acts have been further categorized into different factors such as lack of safety education and training, incomplete rules and regulations, unsafe supervision, poor safety culture and inadequate management [11-13].

2.1.2. Equipment Error

Any undesirable problem or fault that is related to equipment and poses a serious threat to personnel or industry constitutes equipment error. A database study of 284 accidents concluded that design faults and technical errors cause 78% of the accidents [14]. Another study of 1542 accidents revealed that lack of personal protective equipment (PPEs) are the reason behind 39% of the accidents [15]. They are further classified into design error in the equipment, technical error and lack of PPEs.

2.1.3. Human Error

Any error committed by a human or mistake done by an individual, knowingly or unknowingly, at the workplace is termed as the human error. They are considered the prime reason behind the catastrophes and are the reason of 75% to 96% of accidents in maritime industry [16] and in process industries they are considered the cause of 75% of the total accidents occurred [17]. They have been classified into poor skill , inherent proneness, poor behavior and operation error.

2.1.4. Unsafe Environment

Any environment in the workplace that is not suitable for personnel and is an obstacle in completing their tasks in time is termed as unsafe environment. Stressful workers are said to be one of the major contributors in causing an accident [18]. 63% of accidents are caused by poor construction and 70% happen due to hazardous infrastructures such as improper stairs, slippery floors [14]. Physical hazards such as temperature, humidity also are the major hazardous factors [19]. Unsafe process design, job stress and poor physical conditions constitute unsafe environment.

Four latent variables have been selected for research purposes which are Unsafe Acts, Human Error, Equipment Error and Unsafe Environment. These variables have been shown in table.

Table 1: Latent Variables

Latent variables	References
Unsafe Acts	[6-9]
Equipment Error	[20-22]
Human Error	[16, 17, 23]
Unsafe Environment	[19, 24]

Likewise indicators or observable factors of these latent variables observed in the literature have also been shown in the table.

3. HYPOTHETICAL MODEL

In accordance with the studies above, three hypotheses have been proposed, where e1,e2,e3 etc are the errors of the observable factors while D1,D2 and D3 are the error variances of latent factors, with regression weight of 1.

4. MATERIALS AND METHODS

A statistical technique called structural equation modelling is used to analyze the data. Structural equation modelling is a technique that hypothesizes how a construct is defined by a set of variables and what is the link between constructs themselves [46]. The basic aim of structural equation modelling is to estimate the extent to which the sample data correlates with the theoretical background. Latent variables are the one which cannot be measured directly whereas observed variables can be measured directly. Two types of analysis are common in SEM. Path model and confirmatory factor analysis. Path model basically deals with observed variables and is similar to regression but it can incorporate multiple independent and observed variables which make it better than regression in terms of dealing with complexity whereas confirmatory factor analysis deals with latent variables as well as observed

Table 2: Observed Variables

Unsafe Acts	Equipment Error	Human Error	Unsafe Environment
Unsafe supervision [5, 25]	Lack of PPEs [15, 21]	Poor skill [23, 26]	Job Stress [18, 27]
Lack of safety training [28, 29]	Technical error [20, 22]	Operation error [30, 31]	Unsafe Process Design [24, 32]
Lack of rules and regulations [5, 33]	Design error [34, 35]	Inherent proneness [36, 37]	Poor physical environment [38, 39]
Poor safety culture [40, 41]		Poor behavior [42, 43]	
Management issues [44, 45]			

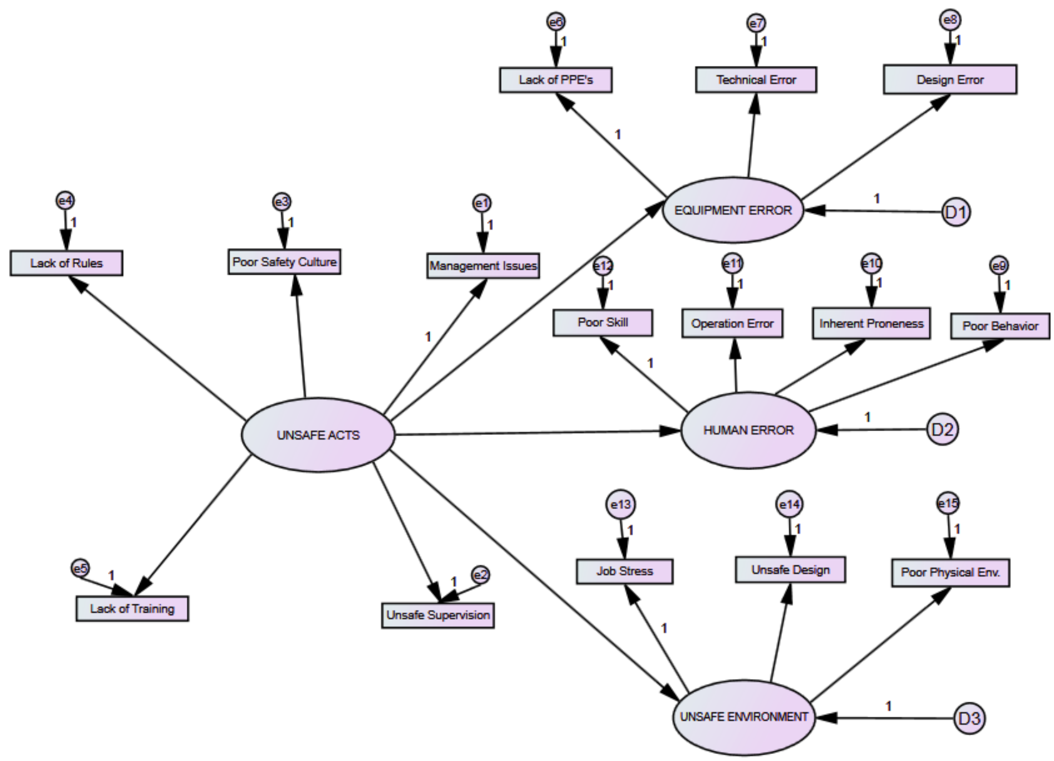

Figure 1: Hypothetical model.

Hypothesis 1. Unsafe acts significantly affect the equipment error (H1).

Hypothesis 2. Unsafe acts significantly affect the human error (H2).

Hypothesis 3. Unsafe acts significantly affect the unsafe environment (H3).

variables whether dependent or independent. Structural equation modelling is basically preferred due to four reasons.

1. Multiple observed variables can be incorporated where traditional statistical techniques deal with limited number of observed variables.

2. It includes validity and reliability of observed variables. When examining statistical data it deals with measurement error which has been sign of relief for researchers.

3. No matter how complex theoretical model is, SEM has the ability to deal with them through multi group SEM models.

4. SEM software programs have become more user friendly than ever having features like windows based software, can be used with ease [47].

4.1. Questionnaire Design and Data Collection

A Likert scale (1-5) questionnaire has been developed to collect data for further analysis. A few questions have been asked regarding demographics of the individuals in the questionnaire and then the questions regarding the mentioned factors have been asked. Questions have been carefully sketched and verified from the research experts.

Table 3: Cronbach Alpha Values

Cronbach alpha for complete dataset	0.874
Cronbach alpha for unsafe acts	0.741
Cronbach alpha for equipment error	0.710
Cronbach alpha for human error	0.741
Cronbach alpha for unsafe environment	0.737

For data collection, among the process industries a textile industry is selected specifically keeping in view the impact textile industry has on Pakistan's economy. Pakistan is among the top textile exporters in Asia, ranked 4^{th} in production of cotton and contributes 5% to the spinning capacity of the whole world with third largest spinning limit [48]. Besides, in Pakistan the most dangerous and accident prone industry that has had most cases of accidents in last ten years is also textile industry. For that purpose a textile industry, Azad textile mills situated at Mangla AJK has been selected as a case study. Azad textile mill is ISO certified organization, has a work force of more than 500 people and was owned previously by the government. Questionnaires have been filled by personnel from all cadres such as managers, electricians, foremen, lab analysts etc. 235 questionnaires have been filled out of which 14 were not filled properly so they have been screened out and in total 221 questionnaires have been considered for data analysis. For SEM, general rule of thumb is N<200 [49].

4.2. Reliability and Consistency

Cronbach alpha is used to estimate internal reliability and consistency. For this purpose, Cronbach alpha for each factor and for complete data set has been calculated. Values less than 0.7 are not good, 0.7 to 0.8 good and 0.8-1 are satisfactory [50, 51]. The Cronbach alpha for complete data set is 0.84 which is satisfactory. For unsafe acts, equipment error, human error and unsafe environment, Cronbach alpha is 0.74, 0.71, 0.741 and 0.737 respectively, which is also good and acceptable.

5. RESULTS AND DISCUSSION

The results of empirical analysis have been investigated and the goodness of fit indices, critical ratios, standard regression estimates have been obtained. Significant variables have been found out by comparing their values with existing standards, hypotheses have been accepted on the basis of the obtained values and the contributory factors have been discussed in detail.

5.1. Goodness of Fit

There are plenty of model fit indices that are used for goodness of fit but it is evident from the recent researches which have repeatedly verified that there are three model fit indices that are most common and most frequently used [52-55]. Results of goodness of fit obtained by calculating estimates in AMOS are as follows:

5.2. Parameter Values

For a relation to be significant it is necessary that p value of each regression weight is lower than 0.05 and all the standardized regression weights have values of

Table 4: Model Fit Summary

Model Fit Indices		Acceptable Fit Indices	Results
Parsimonious fit	Chi square/df	Less than 2	1.586
Absolute fit	RMSEA	0.05 to 1	0.051
	P-Close	Less than 0.05	0.00041

	GFI	0.5 (acceptable)	0.9258
	AGFI	1 (excellent)	0.89771
Incremental Fit	CFI		0.89771

The model seems fit for the analysis and is in line with all the three model fit indices.

over 0.5. If the value of standard regression weight of a factor is below 0.5, it is imperative to neglect that factor.

Table 5: Standard Regression Estimates

Relations	Standard estimates
Equipment error←Unsafe acts	0.609
Unsafe environment←Unsafe acts	0.794
Human error←Unsafe acts	0.889
Management issues←Unsafe acts	0.494
Unsafe supervision←Unsafe acts	0.561
Lack of safety culture←Unsafe acts	0.652
Lack of rules←Unsafe acts	0.61
Lack of training←Unsafe acts	0.60
Lack of PPE's←Equipment error	0.743
Technical error←Equipment error	0.712
Design error←Equipment error	0.589
Poor behavior←Human error	0.634
Inherent proneness←Human error	0.541
Operation error←Human error	0.789
Poor skill←Human error	0.638
Job stress←Unsafe environment	0.733
Unsafe design←Unsafe environment	0.721
Poor physical environment←Unsafe environment	0.647

The standard regression weight of the relationship between unsafe acts and equipment error is 0.609 which means that when unsafe acts go up by 1 standard deviation, equipment error goes up by 0.6097 standard deviations. The standard regression weight of the relationship between unsafe acts and unsafe enviroment is 0.794 which means that when unsafe acts go up by 1 standard deviation, unsafe environment goes up by 0.7945 standard deviations. The standard regression weight of the relationship between unsafe acts and human error is 0.88 which means that when unsafe acts go up by 1 standard deviation, human error goes up by 0.8894 standard deviations. Likwise the relations between unsafe acts with unsafe supervision ,poor safety culture, lack of rules and regulations, lack of safety training have standard regression weights of 0.56, 0.65, 0.60 and 0.59 respectively. However, the relationship between unsafe acts and management issues has standard regression weight of 0.49 which is below the acceptable value of 0.5 and thus can be discarded on the basis of validity. The relation between equipment error and lack of PPEs, technical error and design error has standard regression weight of 0.74,0.71 and 0.58 respectively. The relationship of poor behavior,inherent proneness, operation error and poorskill with human error has standard regression weight of 0.63, 0.54, 0.78 and 0.63 respectively. The relationship of job stress, poor design and poor physical environment with unsafe environment has standard regression weight of 0.73,0.72 and 0.64 respectively.

On the basis of above results, all three hypotheses hold true. i.e. the relationship of unsafe acts and human error has standard regression estimate of 0.89 which means that unsafe acts have the most significant impact on human error. The relationship between unsafe acts and unsafe environment has a standard regression estimate of 0.79 which means that unsafe acts have a major effect on unsafe environment also and the relationship between unsafe acts and unsafe equipment has 0.61 standard regression estimate which means that unsafe equipment is strongly affected by the unsafe acts of individuals.

6. CONCLUSION

In this study a structural equation modelling based approach has been applied to explore the impact of unsafe acts on human, equipment and environment which lead to minor and major accidents which ultimately cause loss of precious lives, damage to the equipment and harm to the environment. The findings of this study are in line with the previous researches which state that unsafe acts significantly contribute to accident causation [11]. Findings also suggest that unsafe acts lead to human error the most, have a significant impact on unsafe environment and also tend to induce errors in the equipment. Proper audits and regular inspections should be done in order to observe the rules and regulations, to make sure that lab design is safe and to make the environment hazard free. Skilled and qualified workers should be hired specifically in the equipment design section. Those who follow the safety procedures should be properly acknowledged, safety workshops should be regularly organized and workers should be given free personal protective equipment such as helmets, gloves, ear buds as needed. This model serves as a guideline for industries and if these safety measures are implemented and observed regularly, it will lead to a safe ,harm free environment and as a consequence, to zero accident vision which is the goal of all the industries in the developed countries.

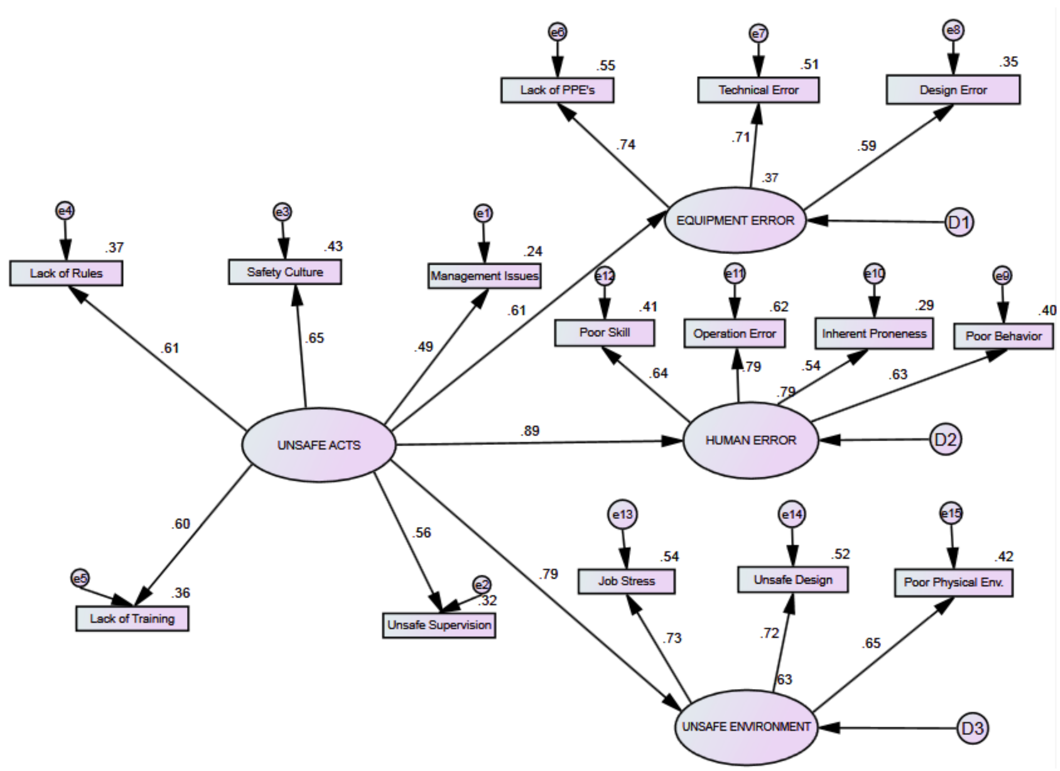

Figure 2: Final Measurement Model.

7. RECOMMENDATIONS

The safety of the industries can be ensured by focusing on the accident causation factors involved in this study. The empirical approach applied in this research involved a case study, in future it is recommended to implicate the similar research of larger sample size or in other industries and find whether the results are consistent throughout the industries or not. In the future prospects, relations among the human error, equipment error and unsafe environment and their interactions can be further explored.

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