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Association between Human Error and Occupational Accidents' Contributing Factors for Hand Injuries in the Automotive Manufacturing Industry

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Abstract

Current studies related with the identification and classification of human error and contributing factors for accidents have been focused mainly on organizational accidents in high risk systems, neglecting occupational accidents in the field of manufacturing industry. The aim of this study was to evaluate the association between some types of human error and the occupational accidents' contributing factors for hands injuries in the automotive manufacturing industry. This research presents a quantitative study with a cross-correlation design. In collecting data, a sample of 225 reports of accidents with lost days of work was used during 2001-2009. The taxonomy used in this investigation was the System Analysis and Classification of Human Factors developed by Reyes (2011). Likewise, in the data analysis a Chi-square test was used to identify significant associations between some kind of human error and contributing factors and a binary logistic regression analysis in order to know the intensity of such associations. Results show that violations are the main type of human error in the automotive manufacturing industry with 62.66% of frequency in the sample and most of the contributing factors were found in the category of unsafe conditions. Also, violations were associated mainly with the contributing factor of machinery and equipment belonging to the same category. We conclude that accidents analysis in manufacturing industry is showing a clear tendency to declare the worker as the main culprit of the accident.

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1. Introduction

The Health and Safety Executive (HSE) describes human factors as the perceptual, mental and physical capabilities of people and interactions of individuals with their job and work environment, and the influence of equipment design and system design on human performance. It also notes characteristics of the organization which influence safety-related behavior at work [1]. The identification and study of human factors is of particular interest for the field of safety as these factors are involved in human errors. Their field is vast as it ‘‘studies the intersection between people, technology and work, with the major aim to find areas where design and working conditions produce human error” [2]. The human reliability study aims to human error [3] .The human reliability is defined as "the body of knowledge related to the prediction, analysis and reduction of human error, focusing on the role of the person in operations design, maintenance, use and management of a socio-technical system".. Human error is a complex construct that has received constant attention among researchers of human factors, has been consistently identified as a contributing factor in a high proportion of incidents in complex and dynamic systems. The dominant definition of human error is raised by Reason who defines it as "a generic term that encompasses all those occasions in which a sequence of physical or mental activities, fails to achieve its desired result and when these failures cannot be attributed to the intervention of some chance " [4].

Analysis of human error and their role in accidents is an important part of developing systematic methods for reliability in the industry and risk prediction. To obtain data for predictive analysis is necessary to analyze accidents and incidents to identify its causes in terms of component failures and human errors [5].Therefore, a proper understanding of human factors in the workplace is an important aspect in the prevention of accidents [6], and human factors should be considered in any program to prevent those that are caused by human error.

A manufacturing process can be conceptualized, as a sequence of physical actions and information processing activities that transforms raw materials into customers’ specified products. The ultimate goal of this process is to create profits and sustain industry growth. This goal cannot be achieved without a stable manufacturing environment. Through carefully designed safety mechanisms, it is expected that this process is robust to preserve the firmly coupled activities remain connected under the interferences of occupational stresses, such as human errors. Even though modern technology is incorporated during the process design and installation stages, the inconsistent performance of human behaviours and unstable quality of hardware often create problems in the manufacturing chain. Unexpected human errors and hardware failures disturb the system activities and initiate fluctuation. Once the magnitude of the fluctuation exceeds the limits of system safety capacity, the manufacturing process is interrupted and industrial accidents occur. Investigators have shown that the human errors have been generally recognized as the major cause of industrial accidents [7,8,4,9,10,11,12,13,14] This problem is aggravated by increasing mental workload of human in modern manufacturing environment and insufficient company resources spending due to the lack of understanding the losses of human errors [15,16]

To prevent and/or reduce occurrence of accidents and incidents, the organizations must work towards reducing human error or making the work system to be more error tolerant. The process of management of human error accidents involves prevention, recovery from errors and containment of the consequences resulting from its occurrence [16]. The first step in this process is error identification, which may allow appropriate prevention and mitigation strategies to be developed for this purpose [17].

The causes of occupational accidents from the human factors perspective have received little attention in the field of scientific research. Available studies related to the topic have been developed mainly for aerospace applications and they have been found insufficient to explain accidents causalities in the manufacturing industry

When human errors occur, actions should be taken to control resulting impacts. It is practical to provide factory managers with a tool to assess the potential human error threats from daily operations [18]. A taxonomy developed to identify accidents´ causes can be useful when is combined with diagnostic methods to prevent such accidents. This paper presents an evaluation of the association between some types of human error and the occupational accidents’ contributing factors for hands injuries in the automotive manufacturing industry using a human error taxonomy.

2. Method

The harness is an exportation product, assembled in Mexico and Ciudad Juárez is a city where the mayor companies in this sector (United Technology Automotive, Yazaki, Delphi, Alcoa Fijikura, Packard Electric System, Electric Wire Products, and Sumitomo) are located. In 1997, the United States imported 5.9 billion and Mexico supplied 63.4% of the total U.S. market harnesses. The assembly is done in 58 plants in some states of Mexico: Baja California, Chihuahua, Coahuila, Nuevo Leon, Tamaulipas, Sinaloa, Guanajuato, Zacatecas, San Luis Potosi, Queretaro City, Mexico State, Tlaxcala, and Colima [19,20]. Harnesses are multiple assemblies with insulated electrical conductors, which are mounted in terminals, connectors, sockets and other wiring products used to connect to a power source (batteries and motors) various electrical components such as lights, instruments and motors and / or care for selected high voltage ignition parts (starters, generators, distributors and spark plugs) in vehicles such as cars, aircraft and ships [21].

A Taxonomy was applied in a corporation that manufactures automotive harnesses for the purpose to evaluate the association between human error and occupational accidents with hand injuries. A Brief description of Human Factors Analysis and Classification System Harnesses Industry (SACFHA) is presented in table 1.The data collection was obtained by reports of occupational accidents with lost of work days that occurred during the period from 2001 to 2009 in a Mexican Harnesses Corporation. The amount of occupational accident reports recorded in the database was 368, of which only 225 reports were useful. The reports provided have the following information: name of the person to whom it happened the accident, age, operator station, description of the accident, type of injury, contributing factors in the crash, causing object, corrective actions take place to avoid that happening again, so the responsibility to perform them.

In order to facilitate data collection form was designed to summarize information about causal factors reported by safety personnel during accident analysis. The category, subcategory, contributing factors and frequency were identified, classified and analyzed using the interpretive method of content analysis. Only four of the five categories that integrates Taxonomy were used, due reports did not present data related to the supervision category. During the analysis of the reports identified the types of injuries caused by accidents and their relationship to human error types.

The tabulation errors and contributing factors was performed with a frequency table. The categories and subcategories of human error and contributing factors were operationalized with categorical variables nominal rate (dichotomous) the next step was to evaluate the relationship between these variables. Associations between types of human error and causal factors contributing were evaluated by cross with Chi-square Pearson test for contingency tables .The intensity of associations tabulations was estimated by a series of binary logistic regression analysis. This model is useful for cases where you want to predict the presence or absence of a characteristic or outcome based on values of a set of predictor variables also estimated the odds ratio (odds ratio) of each independent variable in the model.

In each case, each contribution factor was introduced simultaneously to predict the presence or absence of the type of human error. One advantage of logistic regression is that the exponent of the beta for each indicator is an odds ratio. This expresses the increasing prevalence of error is observed when the contributor is present and otherwise when the factor is not present. A value of odds ratio equal to 1 indicates that the presence of the factor was not associated with a change in the prevalence of error, whereas a value greater than 1 indicates the degree to which the error became more frequent in the presence of the factor and when the value is less than 1 can be taken as an indication that the factor was not associated with an increased prevalence of the error but not necessarily that provides protection factor error. SPSS (Statistical Package for Social Sciences) version 15 for Windows XP statistical package was used for data analysis.

Table 1 Brief description of Human Factors Analysis and Classification System Harnesses Industry (SACFHA).

Organizational Factors

Organizational climate. Safety policies, procedures, practices, and the overall importance and the true priority of safety at work.

Operational process. The formal process by which the vision of an organization is carried out, consisting of operations, procedures and working methods.

Resource management. Human and economic resources, equipment and facilities.

Unsafe supervision

Planned inappropriate operations. Management and assignment, including aspects of risk management and the pace of operations.

Failed to correct known problems. Those cases where deficiencies among individuals, equipment, training and other security related areas are "known" to the supervisor but are allowed to continue uncorrected.

Supervisory violations. The willful failure by the administrators during the course of their duties, in relation to the rules, regulations, instructions or standard operating procedures related to safety.

Inadequate supervision.Oversigth of management of personnel and resources, including professional guidance, training, supervision resources, motivation, leadership regarding operational safety.

Unsafe conditions

Machinery and equipment. Conditions in the machinery and equipment that do not allow the execution of the task safely.

Safeguards. The different ways in which human error can be contained.

Tools. Instruments that help workers to perform their task.

Environmental conditions. Features of the physical environment that may influence occupational accidents such as lighting, noise, vibration, temperature.

Personal factors

Physical factors. Physical characteristics of the operators may influence occupational accidents.

Social factors. Behaviors resulting from workers' social life that influence occupational accidents.

Psychological factors. Behavior characteristics workers that influence in occupational accident

Human error

Mistakes. Errors of conception are based on knowledge and rules established, its detection is difficult, as they can remain dormant over time, can be about rules and knowledge.

Slips. Errors that are related to observable facts and are commonly associated with attention deficits, such as the introduction, omission, investment, given orders wrong and untimely actions.

Violations. This kind of human error are deviations are operating procedures, standards and existing rules regarding safety, may be: routine, exceptional and sabotage.

The routine violations are presented in the level of skill-based behavior and take the least effort to accomplish the task.

Outstanding violations are generated in the working conditions and are interpreted as necessary for the fulfillment of the task.

Sabotage is intentions to harm people or equipment.

3. Results

The results of the associations between types of human error and contributing factors evaluated by cross-Pearson's $\chi 2$ test tabulations are shown in Table 2. Analyses of Chi-square tests indicated that there were significant associations between human error and unsafe conditions category p = 0.000, human error and category of organizational factors p = 0.047, human error with subcategories of machinery and equipment p = 0.000 and human error and tools p = 0.047. Similarly, the Chi-square showed also a significant association between violation and the category of unsafe conditions p = 0.000, in addition to the subcategory violations of machinery and equipment with p = 0.000.

Table 2 Association between Human Error Types and Contribution Causal Factors

Association between variables	χ^2	**g.l**	**Sig.**
Human Error– Unsafe Conditions	29.658	1	0.000*
Human Error – Machinery and equipment	34.124	1	0.000*
Human Error – Tools	3.939	1	0.047*
Human Error – Organizational Factors	3.954	1	0.047*
Violations – Unsafe Conditions	19.678	1	0.000*
Violations – Machinery and equipment	22.007	1	0.000*
Violations – Barriers	0.554	1	0.457
Violations – Tools	2.504	1	0.114
Violations – Organizational Factors	3.704	1	0.56
Slips– Unsafe Conditions	1.882	1	0.170
Slips– Machinery and equipment	3.672	1	0.55
Slips– Barriers	1.331	1	0.249
Slips – Organizational Factors	0.323	1	0.570

The results of the logistic regression equation are showed in Tables 3-8. For this analysis, human error and violations were considered as dependent variables, while the categories of unsafe conditions, personal factors, factors organizations and subcategories of machinery and equipment, tools and barriers as covariates in the model.

Table 3 Logistic Regression Analysis between Human Error and Human Factors Categories.

								I.C. 95.0% for EXP(B)	
		B	E.T.	Wald	gl	Sig.	Exp(B)	Lower	Upper
Step 1(a)	FACTORG(1)	1.097	.434	6.376	1	.012*	2.995	1.278	7.018
	CODINS(1)	2.980	.640	21.646	1	.000*	19.679	5.609	69.042
	FACPER(1)	2.237	.955	5.485	1	.019*	9.362	1.440	60.857
	Constant	-3.967	.639	38.504	1	.000	.019		

Variables introduced in step 1 (a): FACTORG, CODINS, FACPER * Statistical significance at $p < 0.05$

The results in Table 3 shown that when the categories of personal factors, organizations and unsafe factors are related as factors, these have significance. This indicates that the categories were associated with a change in the prevalence of human error, obtaining that of the three categories, the most prevalent was unsafe conditions (CODINS) with an odds ratio of 19,679, followed by personal factors (FACPER) with 9,362 and finally with 2,995 organizational factors (FACTORG).

The table 4 shows the results of Logistic Regression Analysis between human factors subcategories and human error. In this table it can be seen that the factors associated with a change in the prevalence of human error are: machinery and equipment (MAQYEQ) and tools (HERRAMIENTA) with odds ratio of 18,706 and 13,932 respectively, these factors belong to the category of unsafe conditions. Also the category of organizational factors (FACTORG) were associated with human error with odds ratio of 2.843.

Table 4 Logistic Regression Analysis between human error and human factors subcategories.

		B	E.T.	Wald	gl	Sig.	Exp(B)	I.C. 95.0% for EXP(B) Lower	Upper
Step 1(a)	FACTORG(1)	1.045	.444	5.527	1	.019*	2.843	1.190	6.793
	FACPER(1)	1.683	.874	3.713	1	.054	5.384	.971	29.840
	MAQYEQ(1)	2.634	.490	28.858	1	.000*	13.932	5.329	36.424
	BARRERAS(1)	-.696	.740	.886	1	.347	.498	.117	2.125
	HERRAMIENTA(1)	2.929	.790	13.750	1	.000*	18.706	3.978	87.969
	Constant	-3.312	.475	48.658	1	.000	.036		

Variables introduced in step 1 (a): FACTORG, FACPER, MAQYEQ, BARRERAS, HERRAMIENTA * Statistical significance at p <0.05

In the logistic regression analysis between violations and human factors categories were identified contributing factors (Table 5), the categories association were unsafe conditions with an odds ratio of 4.032, followed by organizational factors with 2,235.

Table 5 Logistic Regression Analysis between violations and human factors categories.

		B	E.T.	Wald	gl	Sig.	Exp(B)	I.C. 95.0% para EXP(B) Lower	Upper
Step 1(a)	FACTORG(1)	.804	.356	5.114	1	.024*	2.235	1.113	4.487
	FACPER(1)	.315	.760	.172	1	.678	1.371	.309	6.077
	CODINS(1)	1.394	.313	19.897	1	.000*	4.032	2.185	7.439
	Constant	-1.547	.275	31.687	1	.000	.213		

Variables introduced in step 1 (a): FACTORG, FACPER, CODINS * Statistical significance at p <0.05

Finally, the table 6 shows the results of logistic regression analysis between violations and human factors, As shown in this table machinery and equipment, tools, and organizational factors were statistically significant with prevalence of 4.618, 4.573 and 2.143 respectively.

Table 6 Logistic Regression Analysis between Violation and Human Factors Categories

		B	E.T.	Wald	gl	Sig.	Exp(B)	I.C. 95.0% para EXP(B) Lower	Upper
Step 1(a)	FACTORG(1)	.762	.358	4.523	1	.033*	2.143	1.062	4.326
	FACPER(1)	.165	.763	.047	1	.828	1.180	.265	5.264
	MAQYEQ(1)	1.520	.317	22.991	1	.000*	4.573	2.457	8.512
	BARRERAS(1)	.005	.434	.000	1	.991	1.005	.429	2.354
	HERRAMIENTA(1)	1.530	.643	5.656	1	.017*	4.618	1.309	16.297
	Constant	-1.420	.256	30.663	1	.000	.242		

3. Conclusions

The results of this study show that most reports of accidents in the industry of automotive harnesses are mainly related to the category of unsafe acts (human error). Associations between types of human error causal factors contributing determined the existence of a significant relationship between violations and unsafe conditions. This confirms that the two categories with the greatest impact on accidents in the industry of automotive harnesses are a function of unsafe acts and unsafe conditions. It is also important to mention that with respect to violations was determined that the most influential predictor was unsafe conditions with prevalence of 4.032, which means that a violation has an odds ratio of 4.032 times it occurs when the factor contribution (unsafe) is present than when it is not.

In relation to the contribution that this study presents the main and most important is the health of workers and concludes that the identification of contributing factors in the different categories of SACFHA taxonomy, provide useful information to professionals responsible for occupational health, which may be used in order to design new plans and programs for the prevention of accidents in industrial manufacturing complex automotive harnesses. Similarly, this information helps to apply strategies of human error reduction and its contributing factors rather than general prevention strategies. From the perspective of safety culture that dominates the corporation with person-centered approach, whose main characteristic is to blame the worker responsible for the accident. In this sense it is recommended to work in the formation of a culture with a focus on the system where human fallibility recognition and human error as a result instead of cause approach, it is considered that it is influenced by conditions in people perform. This would structure a more effective system of defense against the occurrence of adverse events.

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