DATA EXPLORATION AND STATISTICAL ANALYSIS OF LOST TIME INJURY IN MANUFACTURING INDUSTRIES

ABSTRACT

Accident (whether major or minor) is unexpected and inevitable due to dynamic nature of work, lack of workmanship, and many industrial activities. Some occur due to negligence, lack of knowledge or skill, improper handling of tools or equipment, and lackadaisical attitudes toward safety precautions. These attitudes result in highly prevalent exposure to dangers by employees in some industries. The study identified two industries with peculiar risk cases and safety conditions, designed questionnaires applicable to accident reporting cases for the industries, model the percentage effect of injuries, illnesses, and fatalities (variables) yearly, and model lost time injuries, illnesses, and fatalities with statistical analysis against the cost of implications. The software used in this study was SPSS version 25, while model built was Multi-linear regression, and a correlation matrix was used to check the relationship between the dependent variable (i.e., cost of implication) and the independent variables (percentage of injuries, illnesses and fatalities). The level of fitness of the variables for Tower Alloys Industries was 92% which is lower than the Lafarge Africa Plc with 99.7%. This proves the level of significant and impact of safety in the latter compare to the former. Apart from the collective significant effect of the variables on the cost, only the % of illnesses have significant effect on the cost with 1.6% in Tower Alloys Industries and 0.2% in Lafarge Africa Plc. The implication is that, the workers' benefits from the two industries is poor and not up to standard. Hence, it is advisable for the two industries that, while thinking safety, the workers' benefits and welfare should follow to avoid workers' absenteeism in the industries.

Keywords: Statistical analysis, lost time, injuries, illnesses, fatalities

1. INTRODUCTION

Every organizational culture is a set of habits, values, thoughts and beliefs geared towards engendering improvement of quality product concerns of such organization [1]. Habit is the bedrock upon which an organization should depend mostly for its state of development areas such as safety, health, and quality environment. If a safety culture is to be created in manufacturing industry, collection of safety observations becomes imperative [2]. Likewise environmental observations will have to be gathered for an environmental awareness to be raised. Safety culture in a standard industrial organization is typically created by a key habit herein referred to as accident reporting.

Safety could be defined as freedom from being exposed to the risk of danger or injury occurring as a result of an accident, the condition of being protected from harm or other danger [3]. Safety can also refer to the control of recognized hazards in order to achieve an acceptable level of risk. Safety is especially important for employers and employees who work in industrial environments because of the higher number of risks in these areas [4]. In a situation whereby safety measurement is being compromised, then it leads to Lost Time Injury (LTI). According to Song [5], Lost Time Injury (LTI) is an injury sustained on the job by an employee, which results in the loss of productive work time. LTI is also known as a lost time incident or lost time case. An injury sustained during operation in industry leads to a lost time injury if the injured worker is no longer capable of performing his or her regular job duties, when time-off is taken for recovery and modified work duties assigned to the injured employee while recovering [6-7].

Hamid [8], added that, the leading causes of construction accidents are management factors, unsafe site conditions, and workers' unsafe actions in many countries worldwide. Management factors, hazardous site conditions, environmental problems, and the industry's uniqueness are the leading causes of accidents in the construction sector in Malaysia. Managerial issues and unsafe actions by the workers are the leading causes of Singapore's fatal accidents [9]. Management failure, workers' dangerous actions, hazardous site conditions, and the industry's unique nature cause major construction accidents in Thailand [10]. The major factors responsible for occupational accidents are found to be workers' behaviors, unsafe site conditions, nature or condition of materials used on-site, and lack of knowledge in risk management in many countries [11]. The main contributing factors causing construction accidents in Nigeria's Industries are the workers' factors, management issues, unsafe site conditions, and the uniqueness of industry [12].

Workers' factors, management factors; unsafe site conditions; physical factors; and the industry's uniqueness are also the contributing factors causing injuries and fatal accidents in many industries in United State [13]. The root causes of construction injuries and fatal accidents in Taiwan are management failure; unsafe working conditions; workers' unsafe action; type of project; and company size [14-15]. The leading causes of construction injuries and fatal accidents in Spain are human and management factors [16-17].

Generally, unserious attitudes to safety contribute extensively to accidents and lead to disability problems coupled with inadequate reports of industry-based surveys. These could also lead to injuries, illnesses, fatalities (i.e. loss of lives, loss of equipment or properties) which may affect the income in industries. Moreover, the aftermath of the accidents such as life time experiences, medical check-ups bills etc., may not be quantified but may have a long time effect on the employees and the industries. There is need to review literatures on reporting model and assess some of the lost time injuries that usually occur to checkmate and improve on the safety performance in industries. This process would enhance the analysis and evaluate the cost implications using the accident reports cases such as injuries, illnesses, and fatalities, through the administration of questionnaires from case studies. The aim of the study is to analyze lost time injury in manufacturing industries using data mining and statistical techniques.

With the application of scientific techniques to analyze lost time injury such as injuries, illnesses, and fatalities against the cost of implications, this study would enable the project manager to have close monitoring and supervision of any given project and avoid accident that may reoccur, and probably result to unexpected cost if the previous activities were taken into cognizance, enable the project manager to maintain adequate number of workers per activity, and on each activity, the project manager would ensure that safety precaution is strictly followed. This study is both a reactive based monitoring and active based monitoring methods in which workers would be sensitized based on experience and data collection and learn from incidents and mistakes in order to make the correct prediction while active based monitoring system would help to make some corrective steps.

2. MATERIALS AND METHODS

The methods considered the materials required to identify the industries with high risk cases and safety conditions: design and administration of questionnaires that covered the activities in industries were developed, evaluation of the percentage effect of injuries, illnesses, and fatalities on yearly basis, statistical analysis of the questionnaire administered for the selected industries to evaluate the cost implications were adopted.

2.1 Design and Administration of Questionnaires

Accidents occur in different forms in many industries. In order to minimize adverse effect of these on the workers and the industries as a whole, this study would analyze the significant effect of injuries, illnesses and fatalities that may result to idle time of activities, loss of properties, etc. through the following prepared questions. These questions were directed to essential workers.

i. What is the name of your industry?

ii. Could you guess the total number of workers on the field for the following year?

a) 2023 ……..
b) 2022 ……..
c) 2021 ……..
d) 2020 ……..
e) 2019 ……..
f) 2018 ……..
g) 2017 ……..
h) 2016 ……..
i) 2015 ……..
j) 2014 ……..

iii. What is the average number of victims from injuries and illnesses for the following year?

a) 2023 ……..
b) 2022 ……..
c) 2021 ……..
d) 2020 ……..
e) 2019 ……..
f) 2018 ……..
g) 2017 ……..
h) 2016 ……..
i) 2015 ……..
j) 2014 ……..

iv. How many times has fatal accidents occurred in the following year?

a) 2023 ……..
b) 2022 ……..
c) 2021 ……..
d) 2020 ……..
e) 2019 ……..
f) 2018 ……..
g) 2017 ……..
h) 2016 ……..
i) 2015 ……..

j) 2014 ……..

v. What is the total number of events in the following year?

a) 2023 ……..
b) 2022 ……..
c) 2021 ……..
d) 2020 ……..
e) 2019 ……..
f) 2018 ……..
g) 2017 ……..
h) 2016 ……..
i) 2015 ……..
j) 2014 ……..

vi. Based on injuries, illnesses and fatalities from accidents been recorded, what are the average cost of implications per year?

vii. Considering the occurrences of these menace, how much do you think has been realized from the year 2014 to 2023?

After the questions have been administered, the study considered the percentage of injuries and illnesses, and the percentage of fatalities depending on the ratio of number of victims from injuries and illnesses, to the total number of workers, and also the ratio of the number of fatal accidents to the total number of events recorded on yearly basis respectively, to ascertain the variations based on the events recorded.

Therefore,

$$\text{Percentage of injuries} = \frac{number\ of\ victims}{Total\ number\ of\ workers} \times 100\% \quad (1)$$

$$\text{Percentage of illnesses} = \frac{number\ of\ victims}{Total\ number\ of\ workers} \times 100\% \quad (2)$$

$$\text{Percentage of fatalities} = \frac{number\ of\ fatal\ accidents}{Total\ number\ of\ events} \times 100\% \quad (3)$$

2.2 Statistical Analysis of the Data

2.2.1 Multilinear Regression Analysis in Matrix Form

This model was incorporated to analyze the lost time injury by investigating and predict the percentage effect of injuries, illnesses and fatalities on the cost of implications. It would also examine the trend of injuries, illnesses and fatalities on the cost expended on workers for their welfares after accident, based on the data acquired. This study is important to predict the cost of implications on yearly basis due to the occurrences of accidents in the industries. Injuries, illnesses and fatalities were classified as the independent variables while the "the cost of implications" was regarded as dependent variables. Therefore, the adopted model for multiple linear regression model in matrix form with three independent variables against dependent variable would be used for the analysis. Mottahedi [18], explained the general form of a multiple linear regression analysis which is expressed as:

$$\hat{y} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon \quad (4)$$

$$y_1 = \beta_0 + \beta_1 x_{11} + \beta_2 x_{12} + \beta_3 x_{13} + \varepsilon_1 \quad (4a)$$

$$y_2 = \beta_0 + \beta_1 x_{21} + \beta_2 x_{22} + \beta_3 x_{23} + \varepsilon_2 \quad (4b)$$

$$y_3 = \beta_0 + \beta_1 x_{31} + \beta_2 x_{32} + \beta_3 x_{33} + \varepsilon_3 \quad (4c)$$

Meanwhile, equations 4a, 4b, and 4c can be expressed in matrix form as:

$$\begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix} = \begin{pmatrix} 1 & x_{11} & x_{12} & x_{13} \\ 1 & x_{21} & x_{22} & x_{23} \\ 1 & x_{31} & x_{32} & x_{33} \end{pmatrix} \begin{pmatrix} \beta_o \\ \beta_1 \\ \beta_2 \\ \beta_3 \end{pmatrix} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{pmatrix} \quad (5)$$

From equation 5, the coefficient of β_0 is represented as 1.

Also, equation 5 can be simplified as:

$$y = X\beta + \varepsilon \quad (6)$$

Where:

$$\beta = (X'X)^{-1}X'Y = \begin{pmatrix} \beta_o \\ \beta_1 \\ \beta_2 \\ \beta_3 \end{pmatrix} \quad (7)$$

And $(X'X)^{-1} = \frac{1}{det(X'X)} . Adjunct\ of\ X'X$ (8)

Where:

Adjunct of $X'X = (Cofactor\ of\ X'X)'$ (9)

Hence, from equation 7, the corresponding value for coefficient of multiple linear regression for β_o, β_1, β_2, and β_3 would be determined.

3. RESULTS AND DISCUSSION

Table 1 and 2 summarized the data acquired from the questionnaire administered to the Tower Alloys Industries, Nigeria Limited and Lafarge Africa Plc, Ewekoro Plant.

Table 1. Tower Alloys Industries, Nigeria Limited (Rolling Division)

Year	Number of workers **(a)**	Number of victims from injuries **(b)**	Number of victims from illnesses **(c)**	Number of fatal accidents **(d)**	Total number of events **(e)**	% of injuries (x_1) $\left(\frac{\boldsymbol{b}}{\boldsymbol{a}}\right)$	% of illnesses (x_2) $\left(\frac{\boldsymbol{c}}{\boldsymbol{a}}\right)$	% of fatalities (x_3) $\left(\frac{\boldsymbol{d}}{\boldsymbol{e}}\right)$	Cost implications (y) (10^7) **(f)**	Profit realized (10^9) **(g)**	Net profit (10^9) $(\boldsymbol{g} - \boldsymbol{f})$
2013	90	03	07	00	19	0.0333	0.0778	0	1.5	0.95	0.935
2014	100	05	08	00	20	0.05	0.08	0	1.5	0.95	0.935
2015	120	07	10	01	20	0.0583	0.0833	0.05	1.55	1	0.9845
2016	140	08	12	01	22	0.0571	0.0857	0.0455	1.6	1.5	1.484
2017	145	10	15	02	23	0.0690	0.1034	0.0870	1.75	2.5	2.4825
2018	150	10	15	02	25	0.0667	0.1	0.080	1.5	2	1.985
2019	170	12	22	03	27	0.0706	0.1294	0.1111	2.5	1.5	1.475
2020	180	15	25	05	30	0.0833	0.1389	0.1667	3	1.2	1.17
2021	200	18	30	06	35	0.09	0.15	0.1714	3.5	1	0.965
2022	220	21	35	07	40	0.0955	0.1591	0.175	4.5	0.95	0.905

Table 2. Lafarge Africa Plc, Ewekoro Plant

Year	Number of workers **(a)**	Number of victims from injuries **(b)**	Number of victims from illnesses **(c)**	Number of fatal accidents **(d)**	Total number of events **(e)**	% of injuries (x_1) $\left(\frac{\boldsymbol{b}}{\boldsymbol{a}}\right)$	% of illnesses (x_2) $\left(\frac{\boldsymbol{c}}{\boldsymbol{a}}\right)$	% of fatalities (x_3) $\left(\frac{\boldsymbol{d}}{\boldsymbol{e}}\right)$	Cost implications (y) (10^7) **(f)**	Profit realized (10^9) **(g)**	Net profit (10^9) $(\boldsymbol{g} - \boldsymbol{f})$
2013	225	25	55	03	18	0.1111	0.2444	0.1667	3.50	7.25	7.215
2014	230	30	60	04	20	0.1304	0.2609	0.2	4.00	7	6.96
2015	235	35	65	05	22	0.1489	0.2766	0.2273	4.50	6.80	6.755
2016	240	40	70	06	26	0.1667	0.2917	0.2308	4.75	6.5	6.4525
20	245	45	75	07	28	0.18	0.306	0.25	5.00	6.5	6.45

17						37	1				
2018	250	50	80	08	30	0.2	0.32	0.2667	5.50	6	5.9450
2019	270	65	90	10	35	0.2407	0.3333	0.2857	5.75	5.5	5.4425
2020	320	80	109	13	40	0.25	0.3406	0.3250	6	4.5	4.44
2021	330	86	116	15	45	0.2606	0.3515	0.3333	6.25	4	3.9375
2022	350	95	126	17	50	0.2714	0.36	0.34	6.5	3.5	3.4350

Tables 1 and 2 are further used to analyze the level of fitness of the model and significant effect of the % of the injuries, % of the illnesses, and % of the fatalities to determine the cost of implication on yearly basis. Based on the report gathered, the industry would be able to investigate and analyze these variables on the cost. Hence, the incorporation of the software package for its analysis.

3.1 Software package for the model

The software used in this study was SPSS version 25 while the model built was Multi-linear regression and a correlation matrix was used to check the relationship.

3.1.1 Tower Alloys Industry, Nigeria Limited (Rolling Division)

Table 3 summarized the level of significant and the fitness of the % of the injuries, % of the illnesses, and % of the fatalities against the cost of implication, while Table 4 explained the coefficients of those independent variables and their significant.

Table 3. Significant Level and the Fitness of the Independent Variables against Dependent Variable

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		df1
					R Square Change	F Change	
1	.959	.920	.880	.36680	.920	22.983	3
Model	df2					Sig. F Change	
1	6					.001	1.293

From Table 3, R-Square determines the coefficient of determination and fitness of the model. Therefore, since the fitness of the model is 92%, it shows that the model is fit. Also the significant of the model F-Change with the value 22.983 or 0.01 which is less than 0.05 means that all the three independent variables (i.e. % of injuries, % of illnesses and % of fatalities) have significant effect on the dependent variable (i.e. cost of implications).

Table 4. Coefficients of the independent variables and their significance

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-3.141	1.546		-2.032	.088
	% of injuries	13.371	25.088	.239	.533	.613
	% of illnesses	50.966	15.351	1.488	3.320	.016
	% of fatalities	-12.570	9.874	-.792	-1.273	.250

From equation 4, for the coefficients of the "% of injuries", "% of illnesses" and "% of fatalities", the value for β_o, β_1, β_2 and β_3 is –3.141, 13.371, 50.966, and –12.570 respectively. Therefore,

$$\hat{y} = -3.141 + 13.371x_1 + 50.966x_2 - 12.570x_3 \quad (10)$$

Equation 10 is referred to as Multiple Linear Regression Model. It shows the effect of the "% of injuries", "% of illnesses" and "% of fatalities" on the cost of implication for the Tower Alloys industry. It implies that, for a particular year, the cost is solely dependent on how much the percentage of the variables are, whereas the percentage of those variables are also dependent on the frequency of the accidents.

However, from the model built, the value of 0.613 and 0.250 for % of injuries and % of fatalities are not independently significant on the cost of implications, only the % of illnesses is significant on the cost and the value of its significance is 0.016. From the findings, it was discovered that the industry is more concerned about the injuries and fatalities which obviously indicates that, to some extent, they take the precautions for safety more seriously, but they are less concerned with the welfare of the workers in terms of their entitlement such as productivity incentive allowance (P. I. A.), weekend allowances, night allowance, height allowance, chemical allowance, non-accident bonus, long service award, provision and blood tonic orheptal, staff uniform or safety boot or staff personal protective equipment (PPE) etc. Table 5 summarized the correlation matrix for the variables.

Table 5. Summary of the correlation matrix for the variables

		% of injuries	% of illnesses	% of fatalities
% of injuries	Pearson Correlation	1	.934**	.966**
	Sig. (2-tailed)		.000	.000
	N	10	10	10
% of illnesses	Pearson Correlation	.934**	1	.966**
	Sig. (2-tailed)	.000		.000
	N	10	10	10
% of fatalities	Pearson Correlation	.966**	.966**	1
	Sig. (2-tailed)	.000	.000	
	N	10	10	10

The symbol ** indicates that correlation is significant at the 0.01 level (2-tailed).

Table 5 also explained the strength of relationships between two variables. Therefore, there is a strong correlation between the % of injuries and the % of illnesses with 93.4%, % of injuries and % of fatalities with 96.6%, % of illnesses and % of injuries with 93.4%, % of illnesses and % of fatalities with 96.6%, % of fatalities and % of injuries with 96.6%, % of fatalities and % of illnesses with 96.6%. Moreover, there is a 2-tailed correlation matrix between the percentage of injuries, illnesses, and fatalities at the level of 0.01.

3.1.2 Lafarge Africa Plc, Ewekoro Plant

Table 6 summarized the level of significant and the fitness of the % of the injuries, % of the illnesses, and % of the fatalities against the cost of implication.

Table 6. Significant level and the fitness of the independent variables against dependent variable

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		df1
					R Square Change	F Change	
1	.999	.997	.996	.06251	.997	755.679	3
Model	df2					Sig. F Change	
1	6					.000	2.331

In the case of Ewekoro plant, F Change is more significant and the model is more fit compare to Tower Alloys Industry. The significant level of F change is 0.000, while R-Square is 99.7%, which determines the coefficient of determination and fitness of the model. Also the significant of the model F-Change with the value of 0.000 which is less than 0.05 means that the three independent variables (i.e. % of injuries, % of illnesses and % of fatalities) have stronger significant effect on the dependent variable (i.e. cost of implications) compare to Tower Alloys Industry. This proves the level of safety in the industry that, despite the amount of projects the industry is engaged with, and the higher risk in the industry, these three variables collectively have more effect on the cost implication per year. If the industry does not consider those variables, it implies that more cost could be expended more than what was planned for, which may have negative effect on the profit for the year. Table 7 explained the coefficients of those independent variables and their significance.

Table 7. Coefficients of the independent variables and their significant

Model		**Unstandardized Coefficients**		**Standardized Coefficients**		
		B	**Std. Error**	**Beta**	**t**	**Sig.**
1	**(Constant)**	**-2.562**	**.736**		**-3.481**	**.013**
	% of injuries	**-3.258**	**3.184**	**-.188**	**-1.023**	**.346**
	% of illnesses	**23.396**	**4.363**	**.928**	**5.362**	**.002**
	% of fatalities	**4.415**	**2.245**	**.261**	**1.966**	**.097**

From Table 7, considering the individual significance of each of the variables on the cost, just like the Tower Alloys Industry, % of illnesses only have significant effect on the cost with the value of 0.002 or at 0.2% while the % of fatalities is not really significant. The significant effect is just at 10% (0.097). The implication is that, since the % of illnesses only have significant effect on the cost, this buoys down to the workers' welfares. There are some entitlements that are accrued to the workers in the industry which they might be deprived of, and can lead to illnesses such as shift allowances, weekend and public holiday allowances, inconvenience allowances, overtime allowances, night work days etc. These are the contributing factors that lead to illnesses. And the higher the frequency of the illnesses, the higher the rate of its effect on the cost.

From equation 4, for the coefficients of the "% of injuries", "% of illnesses" and "% of fatalities", the value for β_o, β_1, β_2 and β_3 is –2.562, 3.258, 23.396, and 4.415 respectively. Therefore,

$$\hat{y} = -2.562 - 3.258x_1 + 23.396x_2 + 4.415x_3 \quad (11)$$

Equation 11 is referred to as Multiple Linear Regression Model. It explains the collective effect of the "% of injuries", "% of illnesses" and "% of fatalities" on the cost of implication ($\hat{y}$). Table 8 summarized the correlation matrix for the variables.

Table 8. Summary of the correlation matrix for the variables

		% of injuries	% of illnesses	% of fatalities
% of injuries	Pearson Correlation	1	.992**	.986**
	Sig. (2-tailed)		.000	.000
	N	10	10	10
% of illnesses	Pearson Correlation	.992**	1	.984**
	Sig. (2-tailed)	.000		.000
	N	10	10	10
% of fatalities	Pearson Correlation	.986**	.984**	1
	Sig. (2-tailed)	.000	.000	
	N	10	10	10

The symbol ** indicates that correlation is significant at the 0.01 level (2-tailed).

Table 8 explained the correlational strength between two variables. However, their relationships for this industry is stronger compare to their relationships in Tower Alloys Industry. The correlation between the % of injuries and the % of illnesses with 99.2%, % of injuries and % of fatalities with 98.6%, % of illnesses and % of injuries with 99.2%, % of illnesses and % of fatalities with 98.4%, % of fatalities and % of injuries with 98.6%, % of fatalities and % of illnesses with 98.4%. Moreover, there is a 2-tailed correlation matrix between the percentage of injuries, illnesses, and fatalities at the level of 0.01.
Considering the work analyzed by Ahmad et al., [19], where the effect of injuries, accidents, and hazards was investigated and evaluated on the productivity and improvement of a selected garments factory. According to them, It was emphasized that, most of the injuries

occurred in the Dying section was as a result of unawareness on the usage of toxic chemicals and personal protective equipment. Furthermore, this study is in line with the work done, that is, apart from the fact that, the variables considered for the two industries have significant effect on the cost, only illnesses also have significant effect on the cost since the management does not look into the welfare of the workers. Hence, this may influence workers absenteeism and productive time for the two industries.

4. CONCLUSIONS AND RECOMMENDATION

This study has been able to establish the effect of the % of injuries, % of illnesses and % of fatalities through a multilinear regression model, and a correlation matrix used to check their relationship. The software package used to implement the model was SPSS version 25. The developed questionnaires helped to investigate and analyze the effects of the independent variables (i.e. % of injuries, % of illnesses and % of fatalities) on yearly basis, and further analyze the correlational strength, and effect of the variables on the cost of implications for the two industries. In spite of the peculiarities from these industries, the project managers need to be cognizant of the safety precautions majorly on the workers as this study revealed that, the % of illnesses solely affected the cost of implication. It is recommended that, the benefits and incentives accrued to the employees or workers on duty should be accorded to them as this would reduce the rate of illnesses. Furthermore, health managers should use enforcement approach on all the workers using the safety rules with penalties to whoever break the rules health wisely. It is also recommended that, the safety officer put more effort to ensure that the environment is clean and free of unwanted objects to avoid injuries and fatalities, so that the limited available resources meant for the project would not be affected.

COMPETING INTERESTS:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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