MACHINE ACCIDENTS AND PROJECT DELIVERY IN KWAZULU-NATAL CONSTRUCTION INDUSTRY

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ABSTRACT

This article identified machine accidents, the number of days lost, cost impact and related accidents in the Construction Industry in the KwaZulu-Natal province of South Africa. Accidents in the construction industry cause severe challenges to the business. The critical parameters for assessing project deliveries are health and safety, cost, time and project quality. The events of accidents on construction premises sabotages these critical parameters of delivery. The main focus of this article was to determine the significance of lost days and the number of accidents on the cost per accident, using the accident data of KwaZulu-Natal from the year 2000 to 2020. Statistical tests were conducted to determine the significance of the lost days and the number of accidents (independent variables) on the cost per accident (dependent variable). Five statistical tests were used in the analysis of the data and tests were grouped into three classes; regression, correlation and paired sample tests. Regression is subdivided into ANOVA, correlation and model summary test. All five tests display the significance of testing variables. The results revealed that there was a significant relationship between the dependent and the independent variables. There was also a positive relationship between lost days and the average cost per accident. At the same time, there was a negative relationship between the number of accidents and the average cost per accident. The positive B value of lost days mean that it directly influenced the average cost per accident. This means that for every increase in days lost to accidents on the site, the costs increased and vice versa. The negative B of the number of days indicated that accidents did not directly influence the average cost per accident. Further, the machine accidents that most caused fatalities were: motorised equipment, truck, lorries, dumpers, building structures, roof work, scaffoldings and staging and wall projections. It is recommended that workers pay more attention to the sources of accidents while working on site.

Keywords: Accidents, Construction Industry Effects, Project Delivery

INTRODUCTION

Most often, the costs of construction accidents depend on the impact during and after the incident. It can be concluded that the more the severity of the accident, the longer the time to return to normalcy and the more the cost incurred in the process. Though insuring projects and workers is as important as executing the project, it is important to acknowledge that insurance will not be responsible for all pay-outs but only cover for severe injuries and damage in line with the insured costs.

Adequate knowledge of construction logistics will help a project manager or an employer handle building construction work with minimal or less severe accidents. Identifying the cause of accidents and the key workers that could be hurt is vital. Once these are done, preventive health and safety measures should be designed, implemented, and monitored to ensure the measures are adhered to always in that specific construction project. This paper covers factors causing machine accidents on construction sites, delay in building construction due to site mishaps, cost effect overview, effects of loss of days on construction works, effects of accidents on the construction industry, effect of loss of days, and number of accidents on the average cost per accident.

The main objective of this article was to determine the effects of lost days and the number of accidents in construction on the average cost per accident. This informs both workers and project managers to prepare carefully toward ensuring an accident-free work environment .

LITERATURE REVIEW

Losses in Construction

Unsafe behaviour is responsible for close to 80 per cent to 90 per cent of construction accidents *(*Oswalda *et al.,* 2015). Upon all safety and precautionary measures put in place, the building construction industry continues to experience a rise in cases of machine-related accidents (Tang et al., 1997). Consequently, it has not stopped. Construction accidents account for about 67 per cent of all industry related occupational accidents (Tang *et al.,* 2004). The more investment in safety, the safer the sector. Some project managers always allocate between 0.25 per cent and 0.5 per cent of the contract sum, to ensure a safe construction environment. They develop a generic method to compute the minor financial safety investment to consider in every construction project.

Tang (2003), defines financial costs in building construction accidents as all losses attributed to accidents in the building construction industry; while economic losses were classified as:

i. Loss from the injured person: Under this category, the injured site worker is compensated for each day of being absent due to the injury sustained on the site up to two-third of his daily wage. The second category under (i) is a case of compensation resulting from a disability that the injured staff suffers as a result of an accident in the cause of duty.

ii Loss due to just resumed, recuperating worker, who cannot perform efficiently at 100 per cent capacity as expected. Equation 1 is used to determine this kind of loss.

Loss = Wage of injured worker × (Day loss × 1/10 + % of disability) ….. (1)

iii Loss as a result of medical fees of the injured person and the cost of conveying injured worker to the hospital.

Iv Loss from fines and legal expenses as a result of workers' accidents in cases where the project manager is fined due to legal claims.

v Loss as a result of inefficiency of other employees due to the occurrence of accidents. This comes in the form of colleagues attending to affected workers, reporting as the case may be, and sometimes weariness from the shock of the accident may lead to some workers stopping work for a moment.

vi Machine and equipment-related losses include loss due to broken-down equipment due to an accident, loss due to work spoiled during the accident, loss when equipment and machines were left idle. At the same time, other workers regain their strength from accident shock.

The overall costs of building construction accidents are a function of the safety performance (Tang *et al.,* 1997). A high accident cost means the safety performance is poor and vice versa. The Accident Loss Ratio (ALR) measures the ratio of the costs of different accidents to the contract sum at separate periods.

Construction Accident costs on the Economy

Accidents cause delay; delays promote reduced productivity, resulting in increased construction costs (Owolabi *et al.,* 2014). Construction sites accident costs can be grouped under direct and indirect costs (Wan Azmi and Misnan, 2013; Williams *et al.,* 2017b). Financial losses due to time and equipment damage resulting from accidents are indirect costs, while medical treatment bills and injury compensations are direct cost (Agwu and Olele, 2014). The proportion of indirect to direct cost is computed to be 11:1 (Holt, 2008; Pillay and Haupt, 2008). In South Africa, the costs of accidents in the construction industry constitute about 5 per cent of the whole construction value, while the United Kingdom and the United States contribute 8.5 per cent and 6.5 per cent, respectively (CIDB, 2009). Contractors are the contributing factors to construction accidents for not meeting the requirement in providing on-site safety information and safety personnel (Kemei *et al.,* 2015).

Table 1: Expected employer costs from accidents

Cost Variable	Descriptions
Fatalities, injuries and absenteeism	Cost of lost work time, production, fines and legal payments
Staff turnover	Replacement training and recruitment costs
Early retirement and disability	Costs associated with retirement, fines and payments to the injured person
Non-medical rehabilitation	Counselling, retraining and workplace changes
Administration duties	Time and effort spent investigating the accident
Damaged equipment	Repair and replacement costs
Insurance premiums	Any increases, refusal, changes in cover or conditions attached
Legal liabilities	Fines, regulatory activity, settlements and associated costs
Lost production time	Losses in production
Opportunity losses	Lost orders, inability to start or finish orders on time
Present time income losses	Loss of income from present and second jobs
Loss of potential future earnings	Loss of income from present and second jobs
Expenses not covered	Medical, travel, new clothing

Source: *(Hrymak and Pérezgonzález, 2007; Mossink and de Greef, 2002).*

Effects of Accidents in the Construction Industry

In a report of the year 2004, about 45 550 cases of workplace accidents and ill health were recorded in three days, and also workplace accidents losses accounted for about €3.3 to €3.6 billion in a year (Mwanaumo and Thwala, 2011; Hrymak and Pérezgonzález, 2007). Table I describes essential variables that affect construction costs as a result of accidents. Thirty-three questionnaires collected from three sectors of labour, agriculture, mines and quarries, and construction industries indicated that the costs reported in construction-related accidents had the highest proportion of all accidents, up to 61per cent (Hrymak and Pérezgonzález, 2007). In a 2005 report of workplace accidents in the United Kingdom, more than one million cases were reported. About forty million days of work were lost, making about 25 000 workforce unable to continue working due to disabilities from accidents (Hrymak and Pérezgonzález, 2007). These coughed out up to £3.3 billion to £6.5 billion from employers, while £910 million to £3710 million were paid as settlement for property and equipment damage during the recorded accidents.

Construction accidents cost a lot more than the recorded or the visible (Mossink and de Greef, 2002). It is difficult to accurately estimate the costs of workplace accidents and ill health (Hrymak and Pérezgonzález, 2007). It causes negative corporate image, loss of days, labour boycott, administrative costs, and many more. The European Union, in 1998, suffered losses approximated between 1 to 3 per cent of the Gross Net Product (GNP) to workplace accidents (Mossink and de Greef, 2002). Losses also included up to 150 million days, and in the year 2002, workplace accidents cost the European Union(EU) and the United States up to €20 billion and €171 billion, respectively.

Compared to occupational accidents in South Africa, construction-related accidents have a considerable impact due to many workers getting injured and killed than in other occupational accidents (Pillay and Haupt, 2008). Globally, accidents in the construction sector gulp up to 4 per cent of Gross Domestic Product (GDP), while in South Africa, it gulps almost 3.5 per cent, which can be quantified as approximately US$4.2 billion. This financial commitment did not account for costs resulting from rising absenteeism at work due to accidents, schedule delays, and poor work attitude when morale was low (Pillay and Haupt, 2008).

The contribution of the construction industry to economic development, is substantial because it contributes a Gross Domestic Product (GDP) of about 7 to 10 per cent in developed nations and about 3 to 6 per cent in underdeveloped nations (Osei, 2013, Giang and Pheng, 2011, Murie, 2007) Construction industry in Turkey has a national employment capacity of about 7.4 per cent and contributes 11.5 per cent to the GNP in the year 2013 (Yılmaz and Kanıt, 2018). The South African construction sector contributes about 4 per cent to the country's GDP (Africa., 2014a). It is classified as the second biggest employer of labour globally, with developing countries' proportion of up to 75 per cent of the global record (Okoro *et al.,* 2016). In South Africa, the construction sector employs about 8 per cent working force and global data accounts for 7 per cent (Africa, 2014b). Therefore, it is a sector that provides diverse job opportunities to the many unskilled workers, thereby enhancing the standard of living (Okoro *et al.,* 2016).

The thought of every contractor, at the beginning of every construction project, is to complete the project without cases of accidents. Still, along the way, accidents happen, and the extent of the impact is not predictable. They only depend on the reactions of the people involved. Construction site accidents can be prevented, thereby minimising waste and boosting performance (Pillay and Haupt, 2008).

Overview of the Cost-effectiveness of Construction Accidents

Work-related accidents, and injuries are burdensome to the employers and affect employees and society in general (Hoła *et al.*, 2017). The South African Department of Labour paid out about R319 million (about $50 million U.S.) as compensations, and medical bills of occupational hazards resulting from work accidents (Pillay and Haupt, 2008).

The ratio of direct costs to indirect costs in construction accidents, differs from place to place and the severity of the accidents. It could be 1 to 67 (Haupt and Pillay, 2016), in the ratio as high as 1:20 and as low as 1:1 (Hinze and Appelgate, 1991); in South Africa, it is estimated to be 1:14.2 (Smallwood, 1999).

In the South African Construction Industry, the three most common machines or equipment related accidents are:

i. accidents where workers are trapped, cut, and or caught in between;
ii. accidents involving being struck by or against, and
iii. accidents due to falls from a height.

(Pillay and Haupt, 2008), published the costs for some kinds of construction industry accidents as paid by the South African Compensation Commission in 2008, they are;

i. Fatal accidents R1 500 000;
ii. Wasted workday R30 000;
iii. Medical attention R3 500; and
iv. First Aid attention R1 000.

In construction accidents, indirect costs, which address relief from injuries and pains, account for about 58 per cent of the financial implications, and production loss, including process delays that takes about 8.4 per cent (Pillay and Haupt, 2008).

As per building and construction activities, work is always expressed as input and output. Input resources include costs expended in executing a construction project and man-hours (Intergraph, 2012). Technology is a significant factor, in ensuring better productivity in building construction works (Intergraph, 2012). Effective labour, accurate planning and data capturing, visualisation of site activities and many more, which enhance timely and cost-effective project delivery, can be achieved using the latest technologies.

Due to the inherent insignificant nature of construction productivity losses, it is always difficult to accurately account for all losses. (Hrymak and Pérezgonzález (2007), researched in Ireland, where the costs and effects of occupational accidents were investigated using twenty case studies. The research indicated that construction accidents culminate in the extended fall in the finance of some of the investigated organisations up to 50 per cent (Hrymak and Pérezgonzález, 2007). Employers also put some methods in place to measure how productivity is affected by costs, as cases of lost days, due to site accidents, were reported. There are always cases of replacement staff for the injured worker, which incur extra wage while medical expenses are still paid for the injured.

Construction accidents have more impact on the finance of small and medium organisations because the organisations do not have enough staff to cover for the injured (Hrymak and Pérezgonzález, 2007). Another reason for preventing accidents in construction companies is that stakeholders spend quite a long time investigating accidents according to the procedure. Over 33 per cent of workers involved in construction accident cases were not involved in any financial commitment, while they were still compensated financially (Hrymak and Pérezgonzález, 2007).

Causes of Machine Accidents in the Construction Industry

Due to the nature of activities, construction environment, equipment capacity and speed, the limited number of highly trained personnel for operating the equipment, and other causes, machine-related accidents are increasing (Niskanen and Saarsalmi, 1983). Many steps are being taken to minimise accidents in the construction industry. Only little is achieved yet (Zhang and D., 2013). About 82 per cent of machine accidents on construction sites were due to lack of necessary training, 80 per cent were due to falling from heights, and 60 per cent were due to electrical equipment, making the construction industry a high-risk industry (Prasad and Rao, 2013; Abukhashabah *et al.,* 2020b, Pinto *et al.,* 2011).

Twenty two percent of the 7.7 per cent of the population of America, that makes the construction workforce, has died as a result of work-related accidents (Kalatpour and Khavaji, 2016, Helander, 1991). The UK's death rate of construction workers rose by 3.7 per cent (Abukhashabah *et al.,* 2020a, Enshassi and Mohammad, 2012). The construction industry integrates different delicate technical operations and triggers accidents when handled properly (Mosly, 2015, Gürcanli and Müngen, 2009). It also comprises different people working on a job at different concentrations, training, experience and state of mind (Hare *et al*., 2006; Im *et al*., 2009).

The two major types of accidents in the construction industry are moving vehicles and stationary machines (Mohan and Zech, 2005).

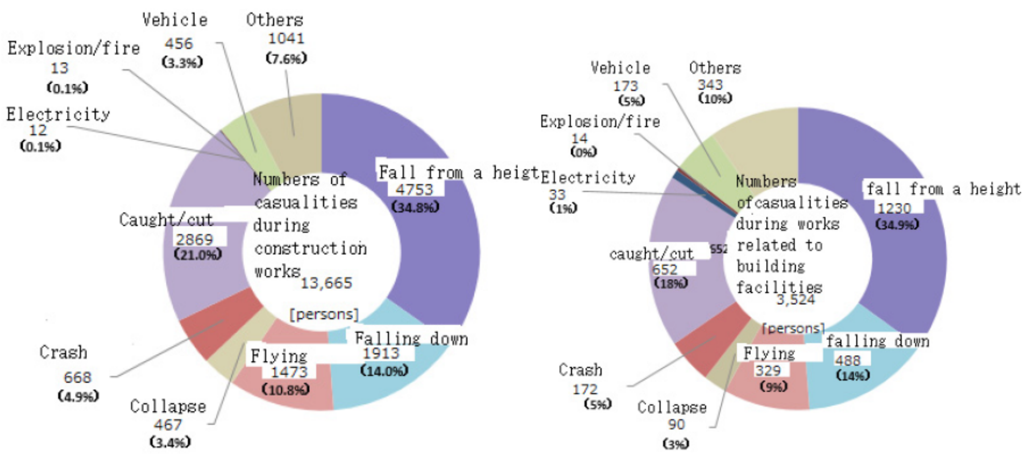

Figure 1. Causes of construction casualties in 2013 (Tamura and Tanaka, 2016).

Machine-related accidents in construction occur while workers carry out their respective responsibilities (Tamura and Tanaka, 2016), meaning the more activities, the more the chances of getting injured. Figure 1 illustrates different accidents recorded between the year 2004 and 2013. It also revealed the causes and the proportion of each in the account of the overall accident.

METHODOLOGY

A method to relate lost days and the number of accidents to the cost lost during machine-related accidents in KwaZulu-Natal, was considered in this article. Data was analysed using SPSS, where values were derived for key determinant components discussed in the next section of this article.

The combined effect of both independent factors was tested against the dependent factor, the average cost of accidents. The analysis also showed that if there is an association between the two factors and the average cost of the accident, what kind of association exist? To test for this, a linear regression model was employed to test a linear relationship between lost days and the number of accidents.

Five related statistical tests were used in the analysis of the data. The data collated included records of lost days, the numbers of accidents and the average cost of an accident. The lost days and the accident numbers were the independent variables, while the average cost of an accident was the dependent variable. The five statistical tests were grouped into three classes; regression, correlation and paired sample tests. Regression is subdivided into ANOVA, correlation and model summary test. All 5 tests display the significance of testing variables.

Correlation was used to determine whether the relationship between parameters showed significance, weak or moderate, high or low. The paired sample test showed the independent factors (variables) effect on the dependent factor (variable). The three regression tests, ANOVA, coefficient test, and a model summary, tested a significant relationship between the predictors and the dependent variable and explained how fit the model variation on the dependent variable was.

FINDINGS AND DISCUSSION

Table 2 presents the recorded data of machine-related accidents in the construction industry in the KwaZulu-Natal Province of South Africa. The table below was extracted from the data of the year 2014, as provided by the statistics of Federated Employer's Mutual Assurance Company (FEM). The impact of the loss of days and the number of accidents was carried out using the accident record from the year 2000 to the year 2020.

Table 2: Indicates Selected Causes of Machine Accidents on Construction Sites, 2019.

JSES	ACCIDENTS PERCENTAGE	FATAL ACCIDENTS	LOST DAYS	NUMBER OF ACCIDENTS	AVERAGE COST PER ACCIDENT
CK, ROCK AND STONE	4.46	0	286	64	18
LDING STRUCTURE	0.21	1	20	3	266,
ORS, WINDOWS & GATES	0.98	0	153	14	28,
CAVATIONS NEC	0.28	0	107	4	75,
NDING WHEELS	0.56	0	117	8	36,
ISTING APP.CHAIN AND BUCKET,ETC.	0	0	0	0	
ISTING APPARATUS - CRANES AND GANTRIES	0.28	0	308	4	397,
ISTING APPARATUS - MECHANICAL	0.42	0	216	6	210,
SC. - CUTTER , N.E.C.	0.28	0	4	4	2,
SC. - MACHINES, N.E.C.	3.55	0	415	51	63,
TORISED EQUIPMENT - TRUCKS, LORRIES, DUMPERS	3.62	4	103	52	60,
LS,SPIKES,FISHBONES	0.63	0	5	9	3,
IECTS FALLING	0.14	0	0	2	31,
IECTS N.O.D.	1.05	0	119	15	85,
NTS,VARNISHES,ETC	0.07	0	126	1	365,
OF	1.25	1	570	18	307,
PES, CABLES & DRUMS	1.53	0	317	22	33,
VS (BAND) WOOD	0.07	0	0	1	41,
V, N.E.C.	0.49	0	12	7	13,
VS (CIRCULAR) WOOD	0	0	0	0	
FFOLDS & STAGINGS	2.65	1	1080	38	66,
PS & STAIRS	1.74	0	177	25	17,
IBER	0.21	0	0	3	5,
LLS (PROJECTION)	0.28	1	101	4	268,

Table 3 shows that the correlating lost days with the average cost per accident gives 0.633**. This means the correlation was significant at 0.01. The correlation between the number of accidents and the average cost per accident was 0.512**. The result meant a stronger correlation between lost days and cost of an accident at 63.3 per cent than between the number of accidents and an average cost of an accident at 51.2 per cent. Since the p-value was significant, it correlated with the outcomes presented in Table 3 that the relationship between the parameters was significant.

Table 3: Correlation Table Showing the Correlation between Variables.

Correlations			**Lost days**	**Number of accidents**	**Average cost per accident**
Spearman's rho	Lost days	Correlation co-efficient	1.000	.827**	.633**
		Sig. (2-tailed)		.000	.000
		N	543	543	541
	Number of accidents	Correlation co-efficient	.827**	1.000	.512**
		Sig.(2-tailed)	.000		.000
		N	543		541
	Average cost per accident	Correlation co-efficient	.633**	.512**	1.000
		Sig.(2-tailed)	.000	.000	
		N	541	541	

** Correlation is significant at the 0.01 level (2-tailed).

Since results presented in Table 3 confirmed a significant correlation between the dependent and the independent variables, a paired sample test was further done to investigate a significant difference between the test variables. Here also, the p-value showed that the difference was significant. In Table 4, the tested null hypothesis showed no association between lost days and an average cost of accidents. Since the p-value was less than 0.05, the null hypothesis was rejected and concluded that there was a significant difference between the lost days and the average accident cost. The second tested null hypothesis showed no association between the number of accidents and the average cost of accidents. Still, since the p-value is less than 0.05, the null hypothesis was rejected. It is concluded that there was a significant difference between the number of accidents and the average accident cost.

Table 4: Paired samples test table displaying the significant difference of the predictors on average cost per accident

	Paired sampled Tests								
		Paired difference							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		T	Df	Sig. (2-tailed)
					Lower	upper			
Pair 1	Lost days average cost per accident	-27466.543824	79745.151377	3428.511845	-34201.39	-20731.68906868	-8.011	540	0.000
Pair 2	Number of accidents	-27648.457741	79830.281720	3432.17184171884	-34390.502157	-20906.413325	-8.056	540	.000

About 13.2 per cent of the variation in the dependent variable (average cost of accidents) was explained by the model. This value was weak to determine the accuracy of dependence. The result of the combined effects of both independent factors was tested against the dependent factor. The average cost of accidents was indicated in Table 5. This explained how both variables collectively affected the costs of accidents. From the model summary in Table 5, a p-value of 0.000 is obtained, which was less than 0.05, suggesting a linear relationship between lost days and the number of accidents with the cost of accidents.

Table 5: Model summary table showing the significance of the independent variable.

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.363a	.132	.128	74525.7929 44	.132	40.799	2	538	.000

a. Predictors: (Constant), NUMBER OF ACCIDENTS, LOST DAYS

If there is an association between the two factors and the cost of the accident, what kind of association exist? To test for this, a linear regression model was employed to test if the linear relationship between lost days and the number of accidents. The model summary table shows a p-value of 0.00, which was less than 0.05. Therefore, there was a linear relationship between the lost days and the number of accidents.

From Table 6, the ANOVA test also showed a significant relationship between the predictors and the dependent variable. Since this relationship was established, the coefficient test revealed the degree of dependence of the significance in the association, which then fit into hypothesis testing.

Table 6: ANOVA table of the variables.

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	453198261800.469	2	226599130900.235	40.799	.000[b]
	Residual	2988102471867.005	538	5554093813.879		
	Total	3441300733667.475	540			

a. Dependent Variable: AVERAGE COST PER ACCIDENT

b. Predictors: (Constant), NUMBER OF ACCIDENTS, LOST DAYS

To determine the degree of dependence of each of the independent factors (lost days and number of accidents) over the dependent variable, average cost of accidents, the coefficient test was further carried out and the results revealed in the coefficient table showed a beta value of 111.568 for lost days, which implied that a positive linear relationship existed between lost days and cost of per accident. In contrast, the number of accidents had a beta value of -1661.291, implying a negative linear relationship. In Table 7, the positive B value of lost days meant it has a proportional influence on the average cost per accident. For every increase in days lost to the accident on the site, the costs increased and vice versa. The negative B of the number of days indicated that accidents do not directly influence the average cost per accident.

Table 7: Coefficient test to present the effect of the predictors on the dependent variable.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	28824.929	3852.362		7.482	.000
	LOST DAYS	111.568	12.389	.542	9.005	.000
	NUMBER OF ACCIDENTS	-1661.291	231.409	-.432	-7.179	.000

a. Dependent Variable: AVERAGE COST PER ACCIDENT

This explains that the accident's impact determined how many days would be lost and how much was lost during the project. In Table 2, four cases of accidents were recorded when using Hoisting apparatus - cranes and gantries, R397 036 and 308 days were lost. In contrast, Motorised equipment recorded 103 days lost to accidents. In fifty-two cases, like R60, 977 was the average cost per accident. The negative value of t and B values in the number of accidents gave us a piece of strong evidence to reject the null hypothesis and concluded that there was a linear relationship between the loss of days and the average cost per accident.

CONCLUSION

Analysing accident cause, with emphasis on cost effects on the organisation's management, is a fundamental step in ensuring that health and safety measures are considered in construction projects execution. The analysis proved that days of no-work due to accidents significantly impacted the overall cost. The analysis had also revealed that the number of accidents played a prominent part in days without work, which invariably affected the cost of construction work. The interpretation of negative t and B values obtained in Table VII meant that emphasis should be on the impact of an accident as the number of accidents did not necessarily affect the cost. This meant only accidents of great severity that kept workers out of a job for days' affected the cost significantly. Therefore, high severity accidents should be avoided at all costs in the construction business, especially those involving cranes and gantries, as seen in Table II. The findings from this exploratory analysis proved that loss of days impacted the value of average cost per accident.

A further and detailed record of data was important to make adequate and prompt steps to minimise accidents in the building construction industry.

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