

Causes of fatality relative to construction site accidents in the KwaZulu-Natal construction industry

Ayodeji Olatunji Aiyetan¹ and Opeyemi Ayobami David²
Department of Construction Management and Quantity Surveying,
Faculty of Engineering and the Built Environment,
Durban University of Technology,
Kwazulu-Natal, South Africa
Email: ayodejia@dut.ac.za; opedavid39@gmail.com

Abstract:

Construction site is a high-risk threatening environment with respect to safety, due to harsh work conditions attracting different kinds of mishaps. KwaZulu-Natal Province has recorded quite a number of accidents attributed to use of machines during construction activities. Based on this the study was initiated and aims to identify causes of machine accidents in the KZN construction industry. A questionnaire survey was conducted. The data for the study were analysed using correlation analysis. Fifty (50) sites were randomly selected and surveyed. The research is limited to construction firms in the KwaZulu-Natal province in South Africa. The application of the result is limited to firms in the KwaZulu-Natal province in South Africa. Findings indicate that fatalities from machine accidents in construction sites can be avoided through observing safety protocols as expected of site workers and machine operators. Further findings indicate that one of the most significant factors of safety is the ability to have skilled, licensed and experienced plant operators. Based on data analysis, the following recommendations were reach: wearing of protective personal equipment whether a staff or allowed visitor, safety evaluation before commencement of construction activities, constant reminder that safety and health is everyone's responsibility.

Keywords: Accidents, Construction, fatality, sites, project delivery

1 Introduction

Construction site is a highly volatile and life threatening environment with regard to safety, due to harsh working conditions, attracting different kinds of mishaps. Behaviour of on-site workers, unfavourable working conditions, arguments and disagreements, carelessness and negligence, people and objects falling from heights, and many more are some of the possible reasons. There have been work principles, safety measures and researches developed toward achieving zero fatalities in site environments. The Province KwaZulu-Natal (KZN) has recorded quite a number of accidents attributed to use of machines during construction activities. Fatality is one of the results of accidents, if accidents can be minimized, then fatalities can equally be minimized.

The aim of this research work is to investigate machine related accidents in the construction industry of KZN through statistical analysis of data on construction site accidents. The causes and the rate of fatality is being assess closely to establish their relationship. This paper also compares and reviews fatalities recorded in construction environment at selected locations. Obtained findings were extensively analysed, while the outcomes of the investigation into the causes of fatal accidents in construction sites are presented. Implementation of these research outcomes is capable to mitigate fatalities caused by machines in the construction industry. This

work also addresses techniques to improved work environment by using safety techniques when working under dangerous conditions.

2 Literature Review

Machinery related accidents occur on construction sites. The frequency of occurrence, cause of accidents, organizational status of victims, factors and effects, are key contributors to fatality in question. These contributors need to be assess to be able to demonstrate potent/viable approach to mitigate or prevent. Some of the causes identified are as follows: insufficient procedure of operation, inadequate machine and tools training, and failure of moving machines. In order to prescribe workable and sustainable solutions to rampant fatal accidents in construction industry, adequate research, investigation and analysis is ultimately necessary. Vasconcelos and Junior, (2015) list major basic safety and health requirements for accident free activities in construction sites:

- i. Efficient health and safety procedures;
- ii. Machine, equipment and spares design;
- iii. Technological advancement and management style;
- iv. Working conditions.

Accidents in construction sites are majorly products of complicated and interconnected causes, such as; mechanical failures, perceptions, faulty technical designs, mode of operations, teamwork and related factors are responsible for fatal accidents in construction environments (Zwetsloot et al., 2013). It is worth noting that one accident cause may not be enough to cause so much damage, as accidents are cause majorly because of complex and connected causes (Smallwood and Emuze, 2016).

2.1. Effects

Fatalities in construction industry account for some losses that threaten project productivity. The effect of the impact may be technically achieve by measuring through available data and scientific procedures. This step is important because this period in South Africa and specifically in KwaZulu-Natal region, a lot of intensive construction projects are ongoing and some concluded. A lot fatal accidents occur every year because of machine used in construction business, making it one of the highly risky industry. (Teo et al., 2005) and (Åsgård and Jørgensen, 2019). Fatalities in construction industry in Korea is on the increase, especially among older workers 45 years and above (Rhee et al., 2013).

2.1.1. Age and Experience effect

As a way of investigating risk groups among construction work environments, it is important to consider workers age and work experience period. (Mučenski et al., 2015) conduct a research that studied the impact of age and years of experience on construction accidents occurrence, the result reveal that jobs that do require training record lesser accidents. Construction workers with short period of experience tend to be more involved in site injury. According to (Levitt and Samelson, 1993), about one-quarter of construction fatalities involve workers with less than 2 months in the work. Out of 143 companies investigated in the US for construction accidents, the result indicates that fatality is about 52% higher among those who were not train, when compared with the trained (Mučenski et al., 2015). Also, age group of 18-34 have the highest construction fatal injury risk; age group 20-24 is about 27% above average, while age group 25-34 is 24% above average fatality rate (Reese and Eidson, 2006). In the contrary, fatalities occurrence in building construction work is minimal in younger age group than older

age group. Age group 50-54 with experience up to 20 years have injury rate close to 70% more than average (Mučenski et al., 2015).

2.1.2. Overview of fatalities in Construction

Reports reveal that up to 52.5% of South African construction sites were not health and safety (H&S) compliant, which is attributed to insignificant influence on site health and safety by construction patrons (CIDB, 2009, Smallwood and Emuze, 2016). The country's DIIR, (Disabling injury incidence rate) is computed to be around 0.98, this means 98 injuries that could lead to disability out of 10,000 workers, while the rate of fatality was determined to be about 0.255 per 1000 construction workers (CIDB, 2009, Smallwood and Emuze, 2016).

The construction industry hires up to 10% work population in advanced nations, but contributes almost 40% work related fatality, while the International Labour Organisation (ILO) puts global figure of annual fatality at 60,000 at the rate of 1 accident every 10 minute (van Heerden et al., 2018). Of about 4,693 occupational fatalities in the US in 2016, construction sector were attributed 21%, ranging from falls from height, caught in-between, electric shock, and struck by moving objects (van Heerden et al., 2018). According to Construction Health & Safety Group report of 2020, construction sector in the United Kingdom has more cases of fatal work related accidents among all sectors as reflected in Figure1. These reviews stressed the need to investigate construction sector data in KZN to know the extent of effects and be able for determine sustainable preventive measures.

Incidents of fatal accidents because of machinery in construction is on the increase (Lee et al., 2016), calling for review of health and safety improvement measures. (Hoła et al., 2017), investigate and analyze 485 construction accidents in Poland, 37% happened to be fatal. Construction accidents are becoming frequent because of flaws and inadequate employee preparations for the work. Employee behaviour contributes to construction accident cases (Drozd, 2016). (Vasconcelos and Junior, 2015) conducted a thorough investigation into the causes and effects of fatal accidents in construction environment. A study of fatality in Portugal reveal that over 709 construction accidents were recorded in a span of three years to proffer and recommend sustainably safe construction work environment (Soeiro and Reis, 2008).

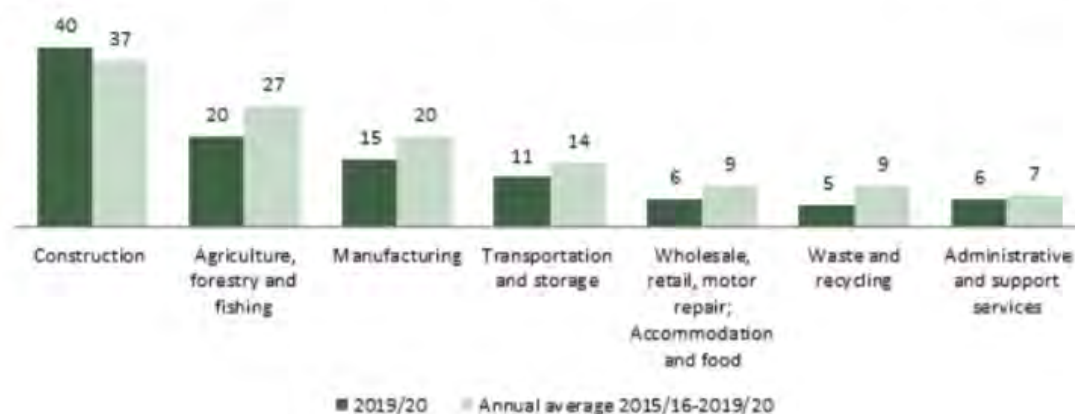


Figure 1. Number of fatal injuries by industry in the UK (HSE, 2020).

Causes because of accident type and cause because of behaviour elements were also analyze among 296 fatal excavation accidents in the US between the year 1997 and 2001 (Arboleda and Abraham, 2004). Scaffold accident accounts for considerably high number of fatal

accidents in construction sites (Ismail and Ghani, 2012). Scaffolds account for 21% of non-fatal construction accidents (Cattledge et al., 1996b). 18.6% of fatalities in construction and occupational injuries between the years 1980 to 1989 were attributed scaffolds (Cattledge et al., 1996a). In Malaysia, scaffolds accident has become a serious issue to be assuaged (Ismail and Ghani, 2012). Error due to crane operation, faulty construction sites design, choice and location of equipment, are some of the causes of accidents (Lee et al., 2016).

2.2 Prevention

Because accidents affect flow of work and cause delays and losses, it should be considered as a component of the construction business, to pay a keen attention to it (Vasconcelos and Junior, 2015). Three interconnected stages were recommended to assuage the effects of construction fatalities, which are technical, human error and socio-technical stages (Swuste et al., 2012). Safety is considered one of the measurements of successful construction activities (Demirkesen and Ozorhon, 2017, Smith et al., 2014), and once jeopardized, it will affect other component of life cycle because of the overlapping effect (Åsgård and Jørgensen, 2019).

There are efforts to make construction site fatality almost zero that is; achieving accident free, injury free construction site (Smallwood and Emuze, 2016). Corrective and mitigating measures should be designed based on the type of equipment used at a particular potential construction accident site (Vasconcelos and Junior, 2015).

3 Research Methodology

The paper thoroughly investigated available data obtained from trusted sources. It was based on the data obtained through questionnaire survey and the statistics of Federated Employer's Mutual Assurance Company (FEM) historical data in the province between the year 2000 and 2020. A survey was conducted by administering survey questionnaires to many construction industry professionals, identified in several construction companies around KwaZulu-Natal province of South Africa. The sample frame was 110 professionals; the sample size was 110 and were administered detailed questionnaire about site safety when using machines on site. A total number of 50 respondents gave feedbacks, which were collated from 22 February to 21 October 2020 from selected construction companies in Durban and analyzed for the purpose of this work. Ninety-five percent (95%) of respondents work in the private sector, while the remaining 5% are with the public sector. The selection of the target construction companies were based on number of employees, year of establishment, number of equipment working in construction sites and the number of accidents recorded. The sample size was drawn from big, medium and small companies.

Analysis of data was performed using Analysis of Variance with F-Test statistics. The question to test is the relationship between the average numbers of machine related fatal accidents in construction industry and their associated causes of accident. The null hypothesis was “the average number of fatality is the same across all causes”, with an alternative hypothesis being “the average number of fatality is different between causes at least one pair of causes. Two approaches were applied at this stage, identified as method 1 and method 2. Out of the 27 identified machine related construction accidents in the province, 12 recorded at least one fatality during the 21 years study period. The first step was to test the significance of the causes of fatal accidents. The method tagged “method one” analyses causes with at least one fatality. The second step analyses all causes of accident based on total causes of accident even without indicating fatality within the study period. All causes without any fatality record were

represented with zero. This will give a better overall statistical interaction of all causes. The interpretation of the hypothesis of interest is “whether the cause of fatalities depends on the number of accidents”. Univariate tests of within-subject effect was performed as “Tests of Within-Subjects Contrasts” and “Tests of between-Subjects Contrasts”. The outcome of the analysis on these are presented in section 4.2.

4 Findings and Discussion

The three approaches to investigating and analyzing machine related accidents in the construction industry of KwaZulu-Natal Province revealed different outcomes whose interpretations are very significant in mitigating fatalities or ensuring zero fatalities. The results from administered survey and interviews reveal that accidents can be avoided if all safety, health, training and behavioural factors are genuinely observed. The three results are presented below.

4.1. Analysis of causes of machine-related accidents with at least one fatality

Table 1 presents the outcomes of the tests. The second column shows their equivalent approximate F-values, with degrees of freedom shown in column two. For one-way within-subjects ANOVA, all multivariate tests yield the same results. For this analysis, the multivariate tests indicate a significant effect since $P < 0.0000001$.

Table 1. ANOVA result of causes with at least one fatality

Variables	Degree of freedom	Sum of square	Mean square	F-statistics	P-value
Cause	12	17.0	1.55	1.88	0.0666
Residuals	48	39.6	0.824		

From Table 1, a P-value of 0.0666 was computed. Because of this value being greater than the significance level 0.05, it means that the null hypothesis is accepted and one can conclude that there are no significant differences between the number of fatalities and the selected causes. This means there is no association between causes and fatality.

From the result displayed in Figure 2, each year recorded fatality because of construction machines. Of all the years between 2000 and 2020, 2019 recorded the highest incidents of fatality 8. The sharp spike may be attributed to a commensurate rise in construction projects or due to mass emigration of skilled workers resulting in a huge vacuum to be filled. From Figure 2, a pattern in the number of annual fatalities within the study time. It could also be as a result of being random it happened because it was not meant to happen and was unexpected. The years 2007, 2013 and 2018 recorded six fatalities each. Prior 2007, there were considerably low machine use fatalities in KZN construction industries, which rose from two in 2002, to three in 2003 and 2004. One could say that after a couple of years of careful occupational practice, negligence creeps in and causing reduced safety and health observations causing a hike in related accident in the subsequent years. This pattern is observed in 2007, 2013, and 2019. It is shocking to see that the highest number of machinery accidents of 519 was recorded in 2002, but fatality of two.

The cause of accident with the highest number of fatal accidents is motorized equipment- (trucks, lorries and dumpers) (ME_TLD) of 34, as indicated in Figure 3. Scaffolds & stagings, recorded 13, but only one fatality was recorded from each of the mixer and hoisting - power shovels, bulldozer, excavator (H_POVSH).

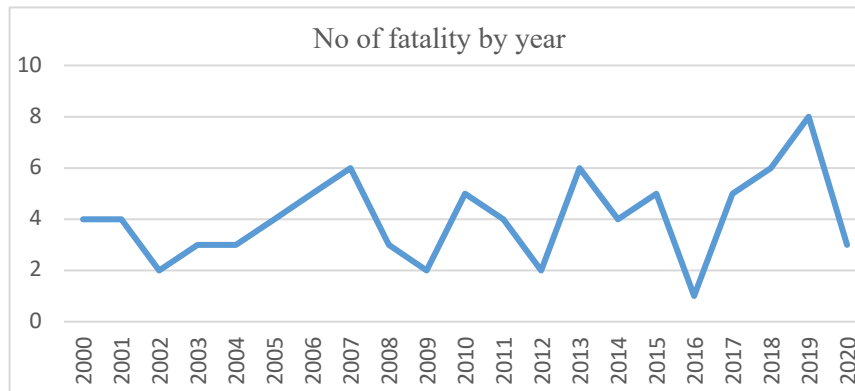


Figure 2. Presents the number of machine-related fatalities in the study period and area.

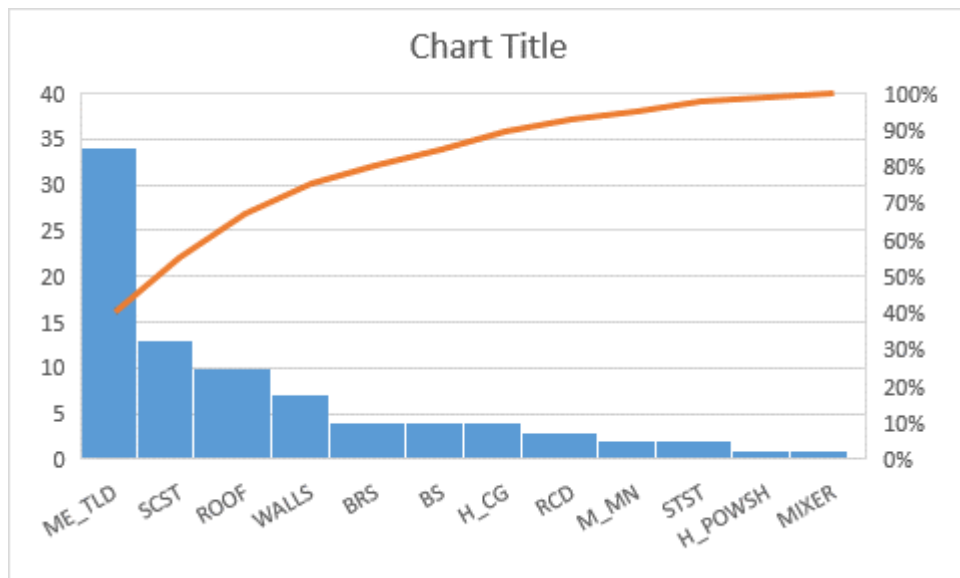


Figure 3. Reflects the frequency of machine-related fatalities, according to causes.

Where: ME_TLD=Motorised Equipment - Trucks, Lorries, Dumpers, SCST=Scaffolds & Stagings, ROOF=Roof, BRS=Brick, Rock and Stone, BS=Building Structure, H_CG=Hoisting Apparatus - Cranes and Gantries, RCD=Hoisting Apparatus - Cranes and Gantries, M_MN=Misc. - Machines, N.E.C., STST=Steps and Stairs, H_POWSH=Hoisting Apparatus Cranes and Gantries, and MIXER=Mixer

A comparison was made of the number of machine related fatalities in construction sites to the total accident recorded within the study period. The outcomes is reflected on Figure 4, indicating the number of fatalities plotted against the number of accidents to check the correlation of both factors. The equation guiding the correlation graph is presented on the graph as y, while the correlation factor is -0.16879. The line graph shows that fatality did not increase or decrease with an increase in the number of accidents. This shows that the number of accidents does not determine the number of fatalities. The degree of correlation between number of accident and fatality is 0.16879, which is about 17% correlated; the negative value also means accident does not result in an increase in fatality.



Figure 4. Correlation between number of accidents and number of fatalities.

4.2. Analysis of all causes of machine-related accidents

Two statistical tools R and SPSS were used in data analysing under this class of investigation. Both tools gave similar outcome, which proves there is an association between the causes of accident and fatalities. The outcome of R is in Tables 2 and 1. The outcome of SPSS is in Tables 3, 4, and 5 below. The values of significance P from both packages were below 0.05, implying significance influence.

Table 2. ANOVA result of all causes of machine accidents

Variables	Degree of freedom	Sum of square	Meansq	F-statistics	P-value
Cause	27	61.1	2.26	12.2	5.95 *10 ⁻⁴¹
Residuals	560	104.0	0.185		

From the result of the analysis on Table 2, a P-value of 5.95×10^{-41} was computed. As a result, of this value being extremely less than the significance level 0.05, it means the null hypothesis is rejected and this means there are significant differences between the number of fatalities and the selected causes. This means there is association between causes of accidents and fatality.

From the Within-Subjects Effects ANOVA Table 6, the F test indicates a significant implement effect, $F = 985.069$, $P = <0.001$. Thus, the type of factor (number of accidents) used does affect the accident that an individual sustain. This buttresses the outcome reveal on Table 2. When there is any reason to doubt the symmetry assumption tests of within-subjects effects, then analysis can be made by reducing the degrees of freedom contributed by the within factors. These adjustments are due to Greenhouse and Geisser and to Huynh-Feldt as on Table 5.

Table 3. ANOVA result of Tests of Within-Subjects Contrasts

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	factor1	Type III Sum of Squares	df	Mean Square	F	Sig.
factor1 (no of accident)	Linear	46753.593	1	46753.593	985.069	.000
factor1 * Cause	Linear	91716.050	27	3396.891	71.570	.000
Error(factor1)	Linear	26578.857	560	47.462		

Table 4. ANOVA result for Tests Between-Subjects Effects

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	48921.960	1	48921.960	989.621	.000
Cause	95146.921	27	3523.960	71.285	.000
Error	27683.619	560	49.435		

These tests are based on degrees of freedom adjustment factor known as ε (epsilon). Although ε must be in the range of 0 to 1, the Huynh-Feldt epsilon can be outside this range. When this happens, the epsilon is set to one. Both Greenhouse and Geisser and Huynh-Feldt epsilons values are revealed on Table 5. The lowest value possible for ε is indicated. Both the numerator and denominator degrees of freedom are multiplied by ε and the significance of the F ratio evaluated with the adjusted degrees of freedom. The adjustment to the F-test is presented below.

Table 5. ANOVA result of Tests Within-Subjects Effects

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
factor1	Sphericity Assumed	46753.593	1	46753.593	985.069	.000
	Greenhouse-Geisser	46753.593	1.000	46753.593	985.069	.000
	Huynh-Feldt	46753.593	1.000	46753.593	985.069	.000
	Lower-bound	46753.593	1.000	46753.593	985.069	.000
factor1 * Cause	Sphericity Assumed	91716.050	27	3396.891	71.570	.000
	Greenhouse-Geisser	91716.050	27.000	3396.891	71.570	.000
	Huynh-Feldt	91716.050	27.000	3396.891	71.570	.000
	Lower-bound	91716.050	27.000	3396.891	71.570	.000
Error(factor1)	Sphericity Assumed	26578.857	560	47.462		
	Greenhouse-Geisser	26578.857	560.000	47.462		
	Huynh-Feldt	26578.857	560.000	47.462		
	Lower-bound	26578.857	560.000	47.462		

4.3. Analysis of the questionnaire survey

From the survey analysis, 56% agreed there were delays due to accidents, 70% agreed accidents ends in disputes. All respondents agreed accidents cause huge financial losses and because of accident, victims incur huge medical expenses. However, none among the respondent agreed to or indicated any case of loss of life. This does not imply there were no loss of life in the industry, but could indicate that organizations where fatalities were recorded were not among the surveyed organizations.

According to the survey, the factor with the most significant influence is to have skilled, experienced and possibly licensed plant operators. The impact of unqualified machine

operators extends to poor maintenance of machines and equipment, which may eventually lead to accidents, waste time, or even delay projects.

5 Conclusion and Further Research

The univariate tests for within-subjects effects require some assumptions for the probabilities provided by the ordinary F test to be correct. Specifically, these tests require certain patterns of variance-covariance matrices. In the fixed effect analysis of variance, we assume that the observations are mutually independent normally distributed and have equal variances.

Fatalities in construction work does not have a pattern for occurring and their occurring are not planned for. They randomly occur, which may be avoided by taking adequate responsibility to adhere strictly to precautionary steps. The increasing tendency of fatal accident due to machine use in construction must be control, since there will be continued use of more machines in construction site, safety behaviour must be enforced using every useful avenue. From the tests and discussions above, conclusion can be reached that most fatal accidents are attributable to non-adherence to safety and health protocols during construction activities.

There is a tangible association between the rate of accidents in construction sites and the number of fatalities. Tests of Within-Subjects Effects, Tests of Between-Subjects Effects, and Tests of Within-Subjects Contrasts involving all the 27 causes all agree that fatality due to machine use in construction business depends on the causes of accident. All computed significance values of $p < 0.00001$.

According to Figure 2, the portion of fatal accidents attributed to motorized equipment is high compare to other causes. It is almost triple the frequency of occurrence in the next cause. This calls for the use of qualified and experienced professionals to handle moving equipment. Reducing fatalities in motorized equipment will change many variables, and this is one of the causes, which experience, age and training can put the value at almost zero.

In the execution of construction projects, aligning to safety and health monitoring is key to maintaining safe construction delivery. The invest in gadgets and safety technology, which may include; wearing of protective personal equipment, safety evaluation at the beginning of construction projects, continuous reminder of the importance of safety and health, knowing it is the responsibility of project participant.

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