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SAFETY EVALUATION OF MECHANICAL EQUIPMENT IN CONSTRUCTION INDUSTRIES

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ABSTRACT
Safety of mechanical equipment in construction companies is of great importance. More user friendly equipment are now being manufactured and maintenance regulations are made so as to make machines safer. Despite these, accidents are still being recorded. Continued accidents and injuries caused as a result of use these mechanical equipment are to be investigated and prevented and therefore the aim of this Study include to, investigate the safety practices in the use of mechanical equipment in construction industries, To evaluate safety effectiveness in the use of mechanical equipment e.g. bulldozers, excavators, payloaders, graders etc., in construction industries, and To develop imaginative proposals to strengthen the industries approach to the control and management of health and safety risks. Possible cause of these accidents are identified from four root areas: machine design, maintenance, human/ personal factors and work issues. Accident records of construction companies were vetted, interviews were conducted with the managers and employees, questionnaires were also administered in order to get the present safety situation of mechanical equipment. Four construction companies whose major activities are road construction were used as samples for the collection of data. The safety in the usage of mechanical equipment was found to still fall below the average in construction companies considered. This is due to the non-use of new machines with better designs for safety and the defective maintenance culture existing in most construction companies.

Keyword: Safety, Mechanical equipment, Construction industries

1 INTRODUCTION
The rate of industrial growth and development is directly proportional to the increase in the use of mechanical equipment. On another hand, the increase in the use of mechanical equipment is associated with resulting mechanical injuries and fatalities. With the rapid industrialization and technological development, most mechanical system are rapidly growing in scale and functionality and it

become more and more difficult to guarantee safety practices, thereby resulting into frequent accidents. Therefore there is need to evaluate the safety of mechanical equipment in construction industries in order to prevent accident or reduce it to the minimum. The importance of safety cannot be neglected due to the role it plays in the society. Sudden unexpected event often disrupt the operation of a system and may likely lead to mishap. These sudden events that end up with bad situation are known as accident. However, accidents have become daily occurrence and have found existence in virtually every activity in the industries. Unnecessary accidents involving machines and mechanical equipment continue to happen. Attempts to change the safety culture in the construction industry has been an uphill struggle and of limited success for a number of reasons. The approach has been to legislate, to culture on sites. In addition to these, a longer term strategy for reducing these accidents would be to design inherently safer machinery and to evaluate the safety condition before putting machinery into use in order to reduce the risk of accidents. It is expected that this will require a change in the safety culture and a greater awareness of the human factors pertaining to mechanical design. Current machinery design may not be as risk-free as it could be because, designers do the minimum, or only what is required to satisfy legislation. The requirement for a risk assessment is satisfied when laid over the design process, often at the end of it and is not required to be an integral part of that process. In order to design and produce inherently safer machinery, it is essential for designers to attempt to foresee the risks associated with the use of a piece of machinery. To do this, it is necessary to consider all aspects of design to include:

- How a machine would be used in normal use
- How it might be used in adverse condition
- How it might be miss-used in order to get a job done more quickly or more easily.
- What the state of mind might be of different people who will come into contact with the machinery.

It is true that risk assessment must embrace these aspects, but machinery must be designed taking into account ease and safety in use and 'foreseeable misuse'. The essential fact is that, to increase safety in use, machineries and equipments must be designed to best fit the people who uses them, rather than for users to

adapt/fit to the design presented. If human factor issues are properly accounted for, then the resultant designs will provide a best fit to all the circumstances of human use (and mis-use), providing a safer environment, resulting in a fewer accidents (Crabb, 2000). Over many years, a great deal of effort has gone into reducing the number of injuries and fatalities as a result of use of mechanical equipment. Researches and initiatives from all sides of the industry have produced a long – term reduction in the number of injuries and fatalities; but recently their effects have diminished and numbers of deaths have even risen. Meanwhile, there has only been limited success in tackling the causes of occupational ill health, which still accounts for the premature death and disablement of many thousands of workers in construction industries. Despite countless health and safety initiatives and campaigns, the industry remains dangerous, what is even worse is that almost all of the deaths and injuries that occur are foreseeable and preventable. We have known for years, how to prevent them, but they still happen- often in the same old ways (Gibson, 2002). The safety of a worker also involves his/her good health. A healthy and contented work force gives back to the employer, a number of very tangible benefits in terms of high productivity, high product quality, lower rate of absenteeism, fewer disputes and increased loyalty and a stable workforce which also means less training expenses for new staff (Akpokoje, 1998). Many people already recognize that good health and safety is not only morally right, but also makes good business sense. International agencies, nations, private and public organizations have been investing enormous human and material resources on safety. This is a reflection of the importance of safety programmes. Indeed in recent times, safety engineering, a branch of industrial engineering, primarily concerned with scientific control of accidents, has received considerable research attention (Garette, 1995), (IAEA, 1996) (Rockwell et al 1970). In construction industries, the use of heavy mechanical equipment (such as bulldozers, grader, excavator, pay loader, etc.) are often involved and of course, injuries resulting from such equipment can be very fatal and severe. The importance of safety therefore, cannot be overemphasized due to the fact that accident, no matter how minor it maybe, will definitely have negative effect on productivity and output. Thus in any industry where financial, mechanical and human inputs have been invested, there is need for safety evaluation in order to effect a desirable output.

The scope of this study is basically limited to construction industries in Nigeria, such as those in Oyo State, Kwara State, and Lagos State

2 *LITERATURE REVIEW*

2.1 Hazard

Hazard refers to the risk or chance of losses that are found in industrial establishment. Information in particular is important in property managing workplace hazards. This encompasses an awareness of problem, an understanding of their nature and a knowledge of how to go about solving them (Sanders and Mc Cormick, 1987)

2.2 Accidents

This occurs in everyday activity. Industrial accident is an unpleasant event that happens in an industrial premise or environment suddenly and unexpectedly with a resultant injury or damage.

2.2.1 Causes of Accidents

Failure to follow known safe procedures, nonexistence and inadequate guarding are common contributing factors (Gardner D. et al, 2000).However major causes of accident associated with mechanical equipment in construction industries, include, disobeying safety rules, inexperience of personnel, human error and risky operation, inadequate safety education and faulty equipment and machine fault. A device which appears to malfunction because it has responded as designed to a bad input is suffering from a command fault (Wikipedia, 2008)

3 MATERIALS AND METHODS

For the purpose of this study, data on some selected mechanical equipment related injuries were collected from selected construction industries. The mechanical equipment studied were collected from selected construction industries. The mechanical equipment studied were mainly earth-moving equipment such as bulldozers, graders, excavators, pay loaders, etc. They were selected because of their common and frequent use in most construction companies. In the survey, injury data from construction activities over a period of time was collected. In order to achieve the stated objectives of this study, some primary data as well as useful information was also collected through:

- Structured interviews
- Self-administered questionnaires

- Record viewing
- Technical checklist

3.1 Analysis of Data

Raw data collected from each construction industry was modified and entered into contingency tables using the chi-square (χ^2). The null hypothesis was tested whether to be accepted or rejected at a particular probability to arrive at a reasonable conclusion. The formula used for chi-square is $\frac{(o^i - e^i)^2}{e_i}$. The data obtained from the four construction companies were also tested for similarity using the ANOVA.

4. *RESULTS AND FINDINGS*

4.1 Number Of Mechanical Equipment Injuries

Of the 165 people who returned questionnaires, 73(44%) reported that they had experienced an injury while 92 (56%) said that they had seen someone else injured.There were differences in the way these questions were answered, because some viewed some injuries as minor compared to others and therefore chose not to account for such.

4.2 Nature Of The Mechanical Equipment Injuries Reported

Through the oral interviews and the self-administered questionnaires, 124 incidents of injury. For the 101 accidents, for which the nature of injury was recalld; open wounds were the most common injuries(63), followed by crushing (22) and amputation (12)

4.3 Factors Associated With Mechanical Equipment Injuries.

4.3.1 Operator Age And Experience

The mean age of workers that are allowed to operate machines in all the companies observed was found to be 26.5 years. The number of experienced workers was also very minimal as the management of these companies make too much frequent changes in machine operators. Of the 165 operators who returned questionnaires, only 30 have worked for a particular company for more than 10years. There was a strong relation between the operator age and experience and the frequency of mechanical equipment injuries. Companies with higher average age and higher level of operator experience had lower number of accidents as viewed from the accident records of the various companies

4.3.2 Operator Literacy

Off all the 165 operators interviewed, none has a tertiary education. Very few of the operators completed their secondary education. Most are either primary or secondary school drop-outs. Some did not even have any form of education. There was a great link between the level of operator literacy and the mechanical equipment injuries encountered.

4.3.3 Machine Age and Model

The mechanical equipment in the various companies were examined and checked. Enquiries as to the age of machine (from manufactured date), the years of usage (years for which it has been involved in continuous use) and the condition of purchase (new or used) were made. Of the companies visited, 192 various types of earthmoving equipment were in constant use. Enquiries showed that the average age of machines was 35 years. It was observed that most of the machines used are old models of between 1976 and 1984. The latest model of earth moving equipment found in use was 1998 model. It was gathered that new models are too expensive and requires high level of technological knowhow which may not be readily available in the country.

4.3.4 Machine Design

A large proportion of machines observed were poorly designed. Of the 192 pieces of machinery examined. 150(78%) were rated as having poor design for safety, 25(13%) were rated as having satisfactory safety design and 17(9%) were rated as having good safety design. The attributes rated for machine design are as follows:

- Existence of traps (between parts)
- Exposed rotating parts (gears, wheels, shafts, spindles)
- Poor control design (knobs in awkward locations)
- No emergency stops
- Exposed moving parts
- Poorly located emergency stops
- Sharp points on the machine exposed (edges, corners, tapers)

Machines often had a combination of design problems. One of the most serious design problem was exposed rotating parts including gears, wheels, shafts and spindles. Companies having the best machine design tended to have the lowest number of mechanical equipment injuries.

4.3.5 Machine Guarding

Of the 192 machines observed, 171(89%)) were considered to require guards on account of exposed moving parts and other hazards but only 95(50%) requiring guards actually had them. However, there was no significant correlation between the existence of guards and the number of accidents reported. Some of the machines with guards and the number of accidents reported. Some of the machines with guards have the guards being poorly designed.

Guards were frequently removed; the most common reason given for removal wa that it was difficult to do the job with the guards in place. Several tasks were observed where the work necessitated removal of guards. Employers and employees discussed the difficulty they had finding or making new guards for old machines which were not built with guards.

4.3.6 Maintenance of Equipment

Of the 192 pieces of equipment checked, 88(46%) were rated as being in poor condition, while 104 (54%) were rated as having satisfactory or good condition. This data was supported by questionnaire findings regarding maintenance. Machine condition was significantly associated with the number of mechanical equipment injuries. The extent of use of machines is also a very important factor considered. Machine used beyond their working limits or used inappropriately are more likely to develop faults which may affect the occurrence of accidents. It was also reported that when low grade machine parts are used to replace worn out ones, such results into faulty machine operation which often caused accidents in construction companies. Companies which use adequate machine parts and does not work the machines beyond their limit tended to have low injury frequency.

4.3.7 Personal Protective Equipment(PPE)

During the examination of the workplace, items of PPE were assessed. It was also noted whether or not workers were actually wearing PPE. There was significant correlation between the condition of PPE and the number of mechanical equipment injuries reported. Results from interview revealed that the managers find it difficult to make employees wear PPE. Employees on the other hand claimed that necessary PPE were not provided for the management. It was

however observed that only few apprentices make use of PPE, while experienced employees were working without PPE. Correspondents also claimed that the use of PPE makes them uncomfortable and inconvenient

4.3.8 Respondents report of cause of accidents

The respondents report based on completed and returned questionnaires were also analysed using the Chi – square (χ^2) method of analysis. Table 1, 2, 3, and 4 shows the descriptive and independence statistics of raw scores of factors in the four companies examined. The tables give the mean value, the calculated and table value of chi-square(χ^2) for each company under the four factors considered as possible cause of accidents.

The null hypothesis and the alternative hypothesis are based on the four factor being considered as follows:

H_{1a}: Present machine design is adequate for the safety of mechanical equipment

H_{1b}: Present machine design is inadequate for the safety of mechanical equipment.

H_{2a}: Present maintenance level is adequate for the safety of mechanical equipment

H_{2b}: Present maintenance level is inadequate for the safety of mechanical equipment

H_{3a}: Present human/ personal factors are adequate for the safety of mechanical equipment

H_{3b}: Present human/ personal factors is inadequate for the safety of mechanical equipment

H_{4a}: Work issues do not affect the safety of mechanical equipment

H_{4b}: Work issues affect the safety of mechanical equipment

Table 1: Descriptive and independence statistics for RCC, Ibadan study (n=42)

No	Factors	Mean	χ^2 (calculate)	χ^2 (table value) p<0.05
1.	Machine Design	2.33	551.18	36.42
2.	Maintenance	1.99	612.99	40.11
3.	Human/personal factors	2.88	475.68	47.44
4.	Work issues	2.87	230.34	25.00

Table 2: Descriptive and independence statistics for KYFY Global Nig. Ltd study (n=56) Ibadan study (n=56)

No	Factors	Mean	χ^2 (calculate)	χ^2 (table value) p<0.05
1.	Machine Design	2.16	550.18	36.42
2.	Maintenace	2.10	516.20	40.11
3.	Human/personal factors	2.81	338.44	47.44
4.	Work issues	2.88	236.84	25.00

Table 3: Descriptive and independence statistics for BULLETIN construction company Ltd. Study (n=32)

No	Factors	Mean	χ^2 (calculate)	χ^2 (table value) p<0.05
1.	Machine Design	2.31	190.67	36.42
2.	Maintenance	2.30	505.86	40.11
3.	Human/personal factors	2.42	134.70	47.44
4.	Work issues	2.50	60.85	25.00

Table 4: Descriptive and independence statistics for FIRST AUG Ltd study (n=35)

No	Factors	Mean	χ^2 (calculate)	χ^2 (table value) p<0.05
1.	Machine Design	2.10	112.56	36.42
2.	Maintenace	2.00	114.42	40.11
3.	Human/personal factors	2.46	114.86	47.44
4.	Work issues	2.52	72.0	25.00

Considering the calculated values and table values of chi-square (χ^2) obtained at 5% level of significance for the factors, for all the four companies, the calculated values exceeds the table value. All the null hypothesis will therefore be rejected while the alternative hypothesis will be accepted.

The man of values obtained for the factors of the various companies also shows that based on machine design and maintenance, the mean approaches the value of 2 for human/ personal factors the mean approaches the value of 3.

The following set of figures shows the model for the four companies with their mean values expressed as percentage.

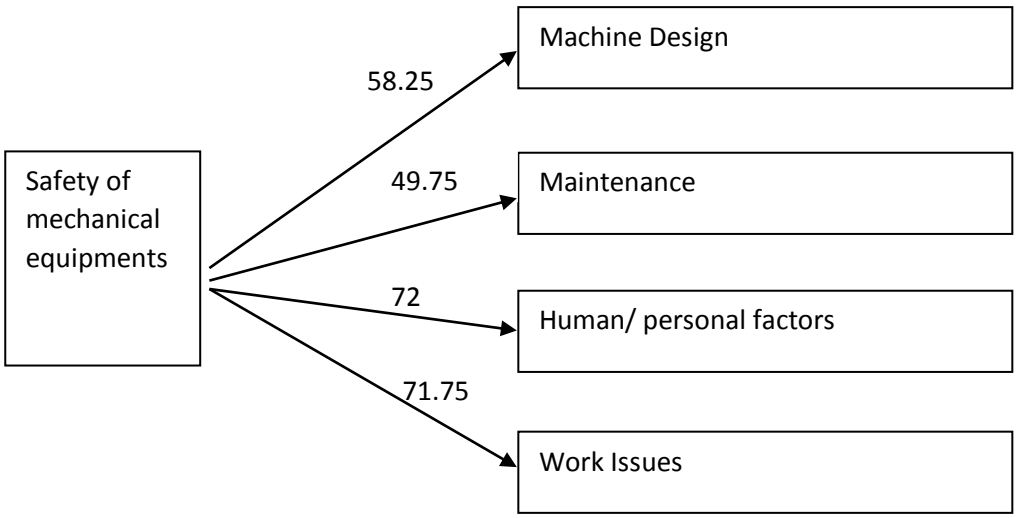

FIG. 1: The modified structural model of Rcc, Ibadan with the mean of each factor expressed as a percentage

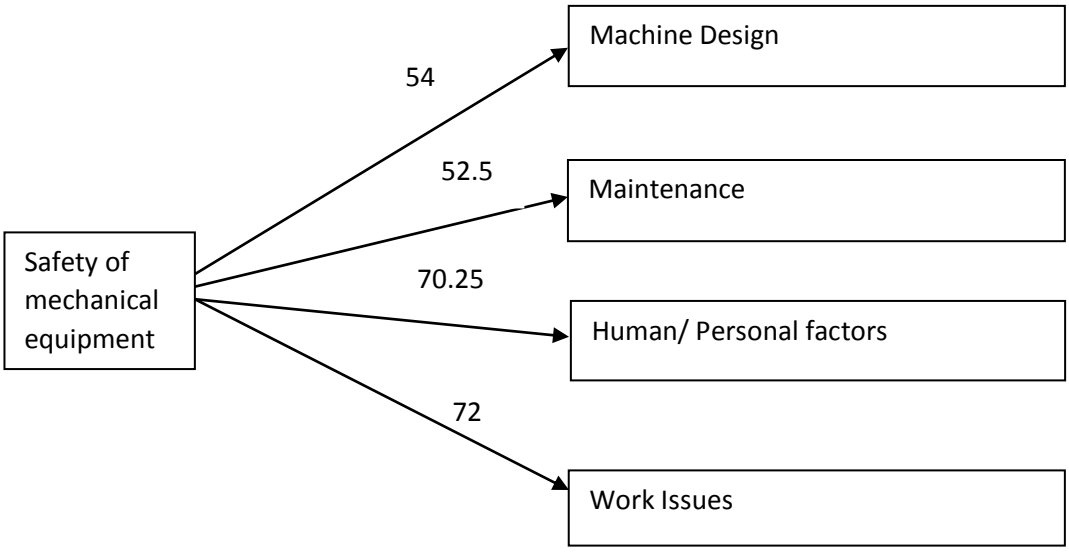

FIG 2: The modified structural model of KYFY, Global Nigeria Ltd. with the mean of each factor expressed as a percentage

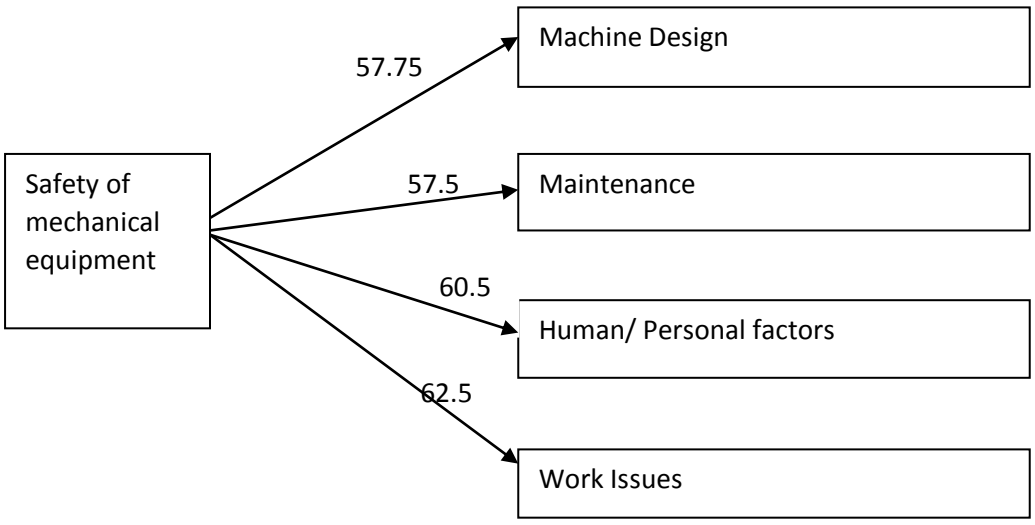

FIG 3: The modified structural model of BULLETIN construction company Ltd with the mean of each factor expressed as a percentage.

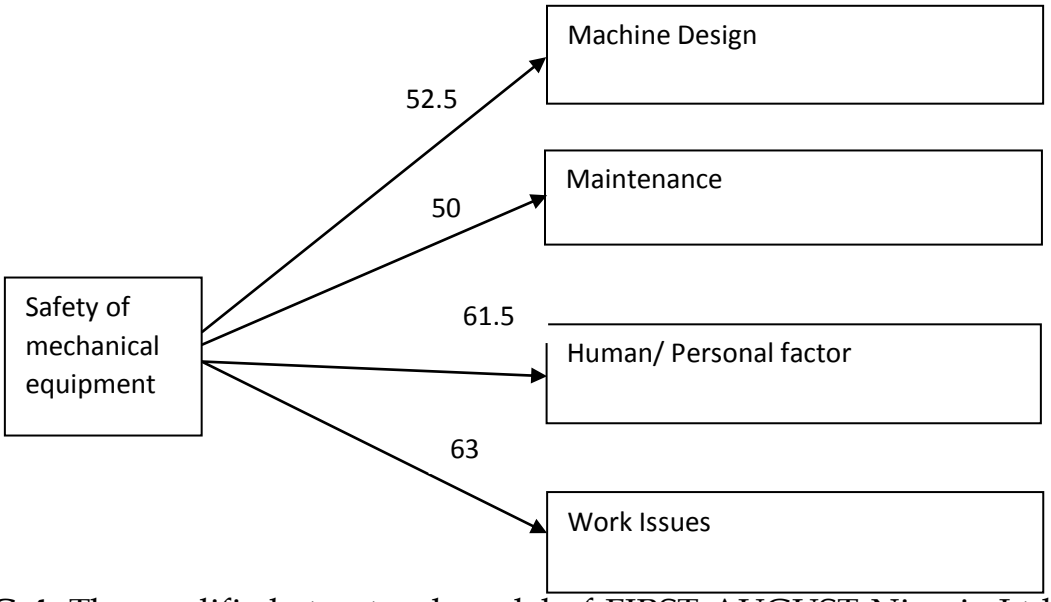

FIG 4: The modified structural model of FIRST AUGUST Nigeria Ltd. with the mean of each factor expressed as a percentage.

Table 5: Results obtained after applying of variance (ANOVA) to the data of the four companies

Source of error	Sum of squares	Variance estimate	Df	F(cal)	F(table)
Between the group	94.61	31.53	3	0.4137	3.49
Within the group	820.14	76.23	12		
Total	914.75		15		

For ANOVA, the following hypothesis were proposed:

H_o there is no significant difference between the data obtained from the four companies.

H_1 there is significant difference between the data obtained from the four companies.

Note that the calculations for table 5

From table 5, the value calculated for 'f' is less than the table value obtained for 'f' at 5% level of significance. Consequently, the null hypothesis H_o will be accepted and the alternative hypothesis (H_1) will be rejected.

4.4 FINDINGS

The study shows that machinery in construction companies were generally old, damaged and not well maintained. Most of the machineries accessed had poor or non- existence safety features, particularly relating to guarding and emergency stops. Lack of safety features was related to the age of the machinery. Older equipment were often manufactured without safety and as machines became older, guards were more likely to be lost or damaged. Although for some machines, low costs guards could be devised which would not be a cheap or easy exercise.

Guards were frequently removed, the most common reason given by respondents was that it was difficult to do the job with the guards in place and several tasks were observed where th workpiece was not suitable for the machine or necessitated removal of guards. The study also indicated that personal protective equipment were not in full use in construction companies. The main reason given by the respondents was inadequacy of the PPE and the discomfort available ones cause.

Poor machine condition was perceived by interviewees to be one of the most important causes of mechanical equipment injuries and observation of machine condition confirmed this is a major problem. The age and condition of the machineries used in construction companies also contribute to machine malfunctions which in turn lead to unsafe conditions. There were also indications that most of the machineries purchased are second hand. The possibility of restricting the sale of old and poorly designed equipment should be further investigated.

The analysis of questionnaire using the chi- square (χ^2) also shows on the average for the four companies that the present machine design, maintenance level, human/ personal factors and work issues in the companies are not adequate enough and does not encourage safety. The mean of the factors expressed as a percentage shows that for machine design and maintenance, the rating is still at the average (between 50- 60%) while human/ personal factors and work issues are still okay (60- 70%)

Finally, the ANOVA analysis shows that the data obtained from the four sample companies are very similar reflecting that almost the same approach is given to safety in the companies

5. *CONCLUSION*

The study evaluates the safety of mechanical equipment in four construction companies. With reference to the results obtained, the following conditions can be drawn:

(i) Even though mechanical equipment with high safety standards is now being manufactured, they are yet to be in use in the country. Old machineries whose design still poses safety threats are in use and therefore create an unsafe environment in the workplace.

(ii) Maintenance culture in construction companies is still not very adequate in the country. With increase maintenance level, the workplace environment will be made safer.

(iii) Safety of mechanical equipment greatly depends on human factors relating to its operation and use. Non adherence to the safety regulations pertaining to the use of mechanical equipment is one important factor responsible for the unsafe condition in workplaces

(iv) Pressures on operators and inadequate safety awareness programmes by the management also influences the continued unsafe conditions in companies.

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