ASSESSMENT OF MAINTENANCE AND FACILITY SAFETY IN SOME SELECTED MANUFACTURING INDUSTRIES IN NIGERIA

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ABSTRACT

The maintenance of equipment and safety of facilities is very important to an industry as it determines its performance. This study aims to evaluate the effectiveness and efficiency of safety and mainte*nance practices to ensuring overall operational performance of some selected manufacturing industries in Nigeria. This paper evaluated the maintenance and safety practices of selected manufacturing industries in Ibadan, Oyo state, Nigeria. It investigated the causes of breakdown, causes of accident and predicted the impact of maintenance and safety practice on production. Questionnaire and personal interaction were employed to collect data on record of maintenance and safety practices, annual record of accidents and machine breakdown from nine manufacturing industries within Ibadan metropolis in Oyo State Nigeria. These were analyzed using existing mathematical models. Equipment maintainability, reliability, availability and causes of equipment breakdown, and accident were evaluated. Results revealed that average maintainability, reliability and availability were 0.648462, 0.764162 and 0.807242 respectively. Average overall economic implications of minor and serious accidents are#533,324,134 and #896,950,921, respectively. Causes of breakdown were identified to be excess workload, failure of parts, untrained operator and inadequate maintenance while unsafe condition and act are responsible for accident occurrences. The Maintenance, safety culture, planning and management in manufacturing industries need more improvement, in order to ensure waste reduction, optimized operational cost, increased productivity and efficiency. Dynamic development of safety legislations from government is encouraged.

Keywords: Maintenance and facility safety, manufacturing, accident causes, causes of breakdown, Ibadan.

INTRODUCTION

Manufacturing is a term most commonly applied to industrial production. It is a process by which raw materials are transformed into finished goods on a large scale. In the same vein, manufacturing industries refer to those industries concerned with the conversion of raw materials, components or parts into finished goods by employing a machine set up with division of labour in a large scale production (Verma, 2010). Since the Second World War, there have been significant technological advancement which rendered old facility obsolete and require updating of the knowledge and skill of maintenance personnel (Waeyenbergh and Pintelon, 2002). In the move towards world-class manufacturing, many firms are realizing a need for the use of proper maintenance of production facilities and systems. Industrial plants, machines and equipment are becoming technologically more advanced and at the same time more complex and difficult to control. With increased global competition for manufacturing, many companies are seeking ways to gain competitive advantages with respect to cost, service, quality, and on-time
deliveries. The role that effective maintenance management plays in contributing to overall
Organizational productivity has received increased attention (Pradhan and Bhol, 2006).Therefore, the importance of the maintenance function has been greater than before, due to its role in maintaining and improving availability, performance efficiency, on-time deliveries, safety requirements and overall plant productivity (Tahboub, 2011). Mohammadi (2016) reported that achieving high production and

productivity target is one of the biggest challenges for in any industry, in order to remain competitive in the global market. The maximum production of equipment is possible by ensuring minimum shutdown and breakdowns to increase the availability of equipment. In other words, the rate of production is highly sensitive to the equipment availability. However, maintenance has defined as a combination of actions carried out to retain an item or restore it to an acceptable standard (Adebiyi et. al., 2004, Adejumo and Babatunde (2010). This standard includes safety reliability and quality of output. This is to ensure that production facilities (equipment structure) are in good condition and available for production at minimum cost. Furthermore, Bolaji and Adejuyigbe (2012)explained maintenance to be seen as a vital part in human and non-human resources management if they are to be continuously functional. It can be summarised as the repair and upkeep of existing equipment, buildings and facilities to keep them in a safe, effective design condition so that they can meet their intended purpose.According toKumar and Kapil (2013), maintenance is characterised as a composite function with immeasurable and intangible benefits, the less the demand, the better the service. It is a necessary evil and a bottomless pit for expenses which usually give to a time lag effect.Equipment maintenance is an indispensable function in a manufacturing enterprise. The recent competitive trends and ever increasing business pressures have been putting maintenance function under the spotlight as never before. For maintenance to make its proper contribution to profits, productivity, and quality, it must be recognized as an integral part of the plant production strategy (Sahu, *et.al.2016*). Shafeek (2012)stated that attention is being turned to maintenance because maintenance expenditures make up a percentage of production costs. Therefore, maintenance activities should include inspection, lubrication, planning, record and analysis, training of maintenance personnel, storage of spare parts (Waheed *et al.,* 2007). Khan and Darrab (2010)reported that the purpose of maintenance is not only to upkeep the plant machinery and equipment preventing them from failure and breakdowns increasing reliability, maintainability and availability of the operating system for maximizing production but also to improve quality and boost higher productivity through improving capacity, faster and more dependable throughout, reducing inventory and lowering operating cost. Rahu, et.al., (2016) noted that in a competitive environment, to be successful and to achieve world-class in manufacturing, the organization must possess both efficient maintenance and effective manufacturing strategies. The effective of maintenance function with engineering and other manufacturing functions in the firm can help to save huge amounts of time, money and other useful resources in dealing with reliability, availability, maintainability and performance issues. Driessen et. al. (2010) noted that high availability of spare parts is important as it influences maintenance delay directly in the case of corrective maintenance or indirectly, in the case of preventive maintenance. Maintenance on a capital asset is conducted according to a maintenance policy, maintenance program, maintenance planning or a modification plan. Saltoglu, et. al., (2016) reported downtime as very complex components that rely on season type, business environment , schedule or unscheduled type of downtime and some other factors. For these, either type of downtime is expensive and inevitable

Bengtsson and Kurdve (2016) emphasized that for better productivity and profitability more emphasis must be paid on maintenance and its management. Ismail et.al., (2016) the implementation of a maintenance management system faced many issues due to defect repetition and lack of proper structure management planning. The technical category of the maintenance task is comprised of maintenance services and its quality, the methods, resources, materials and control strategies required for maintenance (Pophaley and Vyas, 2010)Total productive maintenance (TPM) is an innovative idea recommended by Minh (2011) it leads to productive maintenance which is to maximize plant and equipment effectiveness to achieve the optimum life cycle cost of production equipment. TPM is maintenance that involves all employees in the organization and accordingly includes everyone from top management to the line employee: this encompasses all departments and units including maintenance, operations, inventory and stores, as well as accounting. Haftor (2010) suggested that employing Information Technology ICT in general planning of the conduct of maintenance will not only safe time but safe cost. Significant advances in computer hardware and software development have affected most areas of business and industry, and the area of maintenance planning and management is no exception

The planning and management of productive maintenance activities in industrial manufacturing organizations can however be improved by computer knowledge (Mukattash, 2011) However, as essential as maintenance of equipment and machinery is to an industry, so the safety of its workers is also very paramount. According to Sarma (2009), the concept of safety is probably as old as the history of mankind itself. It is that profession which is concerned with the scientific analysis of the causes of accidental

death and their elimination or reduction. Safety is an action(s) or step(s) timely taken to avoid occurrence of detrimental effect to human or equipment. Such effect may be physical, mental, financial or at times loss in hours (Adebiyi *et al.,* 2005).On the other hand, safety means freedom from the occurrence or risk of injury or loss (Aswathappa, 2004). He described industrial or employee safety as the protection of workers from the danger of industrial accidents. Safety can as well be referred to as the absence of injuries due to the interaction of the employee and the work environment (Lucas, 2001). In a general perspective, safety means a condition of being safe from undergoing or causing hurt, injuries or loss.

The burden of workplace hazards remains a major concern to all. Viewed from all occupational health indices, including human sufferings and related economic costs, the magnitudes of global impact of occupational accidents, diseases, and industrial disasters are alarming, and therefore deserve serious attention (Ezejiofor, 2014). As a result, safety has become a primary consideration in any manufacturing set up and safety consequences have and will remain a matter of continuing interest.(Hoes, 2003)Safety constitutes one of the essential human needs, as postulated by Abraham Maslow in his theory of needs hierarchy. Feeling safe, at work ranks as a very important factor in job satisfaction (Kreitner, 2007). In attempt to satisfy this need certain organizations incorporate into their policy thrusts, guaranteeing workers' safe work execution under a climate capable of enhancing the physical, mental, and emotional conditions. Organizational policy of this nature is often categorized under health and safety(Emmanuel, 2011)

This study is focused on the assessment of maintenance and facility safety in some selected manufacturing industries in Nigeria, the safety and maintenance practice or measures involved in the training of companies' personnel to meet with the challenges presented by various hazards.

MATERIALS AND METHODS

Data were collected on yearly basis for ten years from selected manufacturing industries in Nigeria, on record of maintenance and safety practices, annual record of accidents and annual record of machine breakdown through structured questionnaire, personal interaction and documentation. Nine manufacturing industries within Ibadan metropolis were visited. Average of 10 – 20 copies of questionnaire were administered in each company. The data collected were analyzed using statistical analysis system (SAS), specifically Microsoft excel spreadsheet (2007).The performance measures used for maintenance assessment are equipment maintainability, reliability and availability while those used for safety assessment are frequency and monetary value of accident.

According to Bolaji and Adejuyigbe (2013) the Mathematical models used for maintenance practices may be given as:

$$\text{Availability} = \frac{MTBF}{MTBF+MTTR} \quad (1)$$

Where MTBF = mean time between failure and MTTR = mean time to repair

To achieve high level of availability i.e. those approaching unity or 100%, the MTTR value must be reduced and this implies that the system can be maintained relatively easily.

Failure rate is also known as hazard rate and can be denoted by λ. It can therefore be expressed as

$$\lambda = \frac{Numberoffailurerate}{Numberofyearsofoperation} \quad (2)$$

When the duration of repair times is exponentially distributed, the maintainability function, M(t) is given by:

$$M(t) = 1\text{-}e^{(\frac{-t}{MTTR})} \quad (3)$$

Where (t) is the variable repair time, M (t) denotes the probability that when repair begins at time t=0 it will be accomplished successfully in good time. For the exponential case, the mean time to repair is given by

$$MTTR = \frac{1}{\mu} \quad (4)$$

Whereμ is the repair rate

Also, adopting equipment reliability model which is described by the exponential distribution (Lusser's equation), and random failures

$$R = e^{[-(\lambda * t)]} = e^{\left[-\left(\frac{t}{\theta}\right)\right]} = e^{(-N)} \quad (5)$$

Where t = mission time (1 day, 1 week, 1 month, 1 year, etc which you must determine). λ = failure rate, Θ = 1/λ = mean time to failure or mean time between failures, and N = number of failures during the mission.

According to Adebiyi *et al* (2005) the economic value of accident may be given as

$$V_{iy} = x_{iy}a_i \quad (6)$$

Where

V_{iy} = economic value of accident class *i* in period *y*

x_{iy}= number of occurrence of accident

a_i= standard cost of accident class *i*

i = classes of accident

i = 1… *N*

N = number of identified classes of accident

Summing over *N* classes of accidents in period *y*,

$$V_{oy} = \sum_i^N x_i\, a_i \quad (7)$$

Where

V_{oy} is overall economic implication of accidents

Therefore equations (6) and (7) together with the standard cost of each class of accidents were used to

evaluate the economic implication of each class of accident as well as overall accidents.

However, Adebiyi and Ajayeoba (2011) cost of accident may be estimated as :

$$C_i = [f[\gamma z + N[\frac{(1+t)^{L-T}}{(1+t)^{L-T}-1}]] + MHR\Theta + Q_i + \beta_i \alpha] \quad (8)$$

Where

γ= Establishment average annual salary

z= Establishment maximum allowable service year (year)

f= Degree of Severity

L= Severity life of the equipment involved in the accident (year)

t= Interest

N= Acquisition cost of damaged equipment (#)

MHR = Machine Hour Rate (#/N)

Θ_i = period of idleness of equipment due to accident (T)

Q_i = Value of goods/ materials damaged in accident class *i* (#)

β_i = Total production downtime due to accident class *i*

α = Establishment's overall hourly cost of production (#/N)

i= counter of class of accident

G= Number of identified class of accident

1= Fatal

2= Serious

3= Minor

Note

$a_i = C_i$ = Estimated Cost of accident

Therefore,

Economic value of accident class *i* in period y, $V_{iy} = x_{iy}C_i$

Overall economic implication of accidents, $V_{oy} = \sum_i^N x_i C_i$

RESULTS AND DISCUSSION

Table 1 shows the maintenance performance ratios used to assess the maintenance practice of the selected manufacturing industries. It reveals that in industry A, maintainability of equipment was 58 %, equipment availability is 78 %, and equipment reliability was 78 %. Maintainability of equipment in Industry B was 80 %, availability of equipment was 87 % and equipment reliability was 78 %. In Industry C, maintainability of equipment was 73 %, availability was 80 % and equipment reliability was 72 %. In Industry D, equipment maintainability was 63 %, availability of equipment was 80 % and equipment reliability was 78 %. In Industry E maintainability of equipment was 25 %, equipment availability was 78 % and equipment reliability was 92 %. In Industry G, equipment maintainability was 89 %, equipment availability was 82 %, and equipment reliability was 61 %.

Summarily, Industry E has the lowest equipment maintainability but the highest reliability. This means that equipment in the industry is of a more sophisticated structure and due to the complexity of the equipment, the efficiency of maintenance crew still need to be improved. They often resolved into repair by replacement method which led to increased availability of equipment. On the other hand, Industry G has the highest maintainability, this was observed to be due to the obsolescence of the equipment which requires less skill from the maintenance crew to maintain. This therefore saves cost and leads to a higher availability of equipment but reliability is not as high as when the failed parts were replaced with new ones. This trend is similar for other industries. Deductions from table 1.0 reveals that reliability is directly proportional to maintainability with exception of company E. Although, it was observed that Company E has more modern equipment and machineries than others, this suggests the likelihood of the state of machinery and equipment working condition on maintainability. Lastly, availability, reliability and maintainability is noticed to be interconnected in reality.

Table 1.0: Maintenance Performance Ratios

INDUSTRY	AVAILABILITY	RELIABILITY	MAINTAINABILITY
A	0.776786	0.778801	0.581048
B	0.866310	0.778801	0.802101
C	0.80000	0.718924	0.732865
D	0.798387	0.778801	0.628423
E	0.783784	0.923116	0.251736
G	0.818182	0.606531	0.894601

According to figure 1, it was observed that the factors responsible for equipment breakdown were; Excess workload, Failure of parts, untrained operator and inadequate maintenance. Results showed that 46 % of all the respondents across the industries supported that breakdown was due to failure of parts, 40 % of them attested that breakdown was due to excess workload, 5 % stated that breakdown was due to untrained operator, 7 % supported that breakdown was due to inadequate maintenance while the remaining 2 % gave no response.

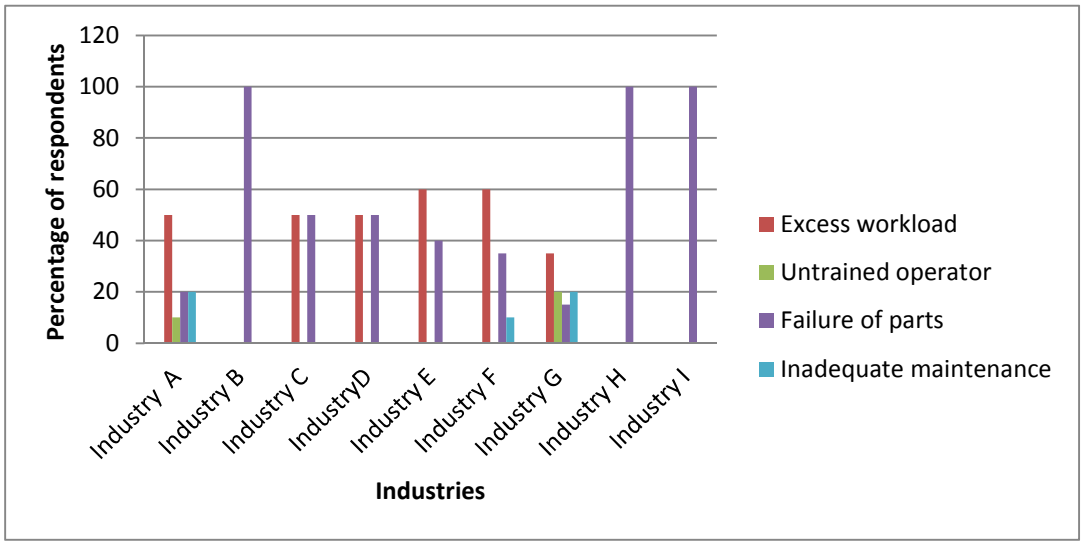

Fig. 1: Causes of Equipment Breakdown

Figure 2 reveals that 75% of all the respondents across the industries stated that accidents were mostly due to unsafe acts. This is as a result of lack of compliance with safety practices by the worker and poor safety policy in the industries in terms of lack of motivation and enforcement, inadequate resources and training, however, it may be deduced that Safety management in those companies need more improvement for better performance. 17% of the respondents stated that accidents occurred due to unsafe condition, while the remaining 8% gave no response.

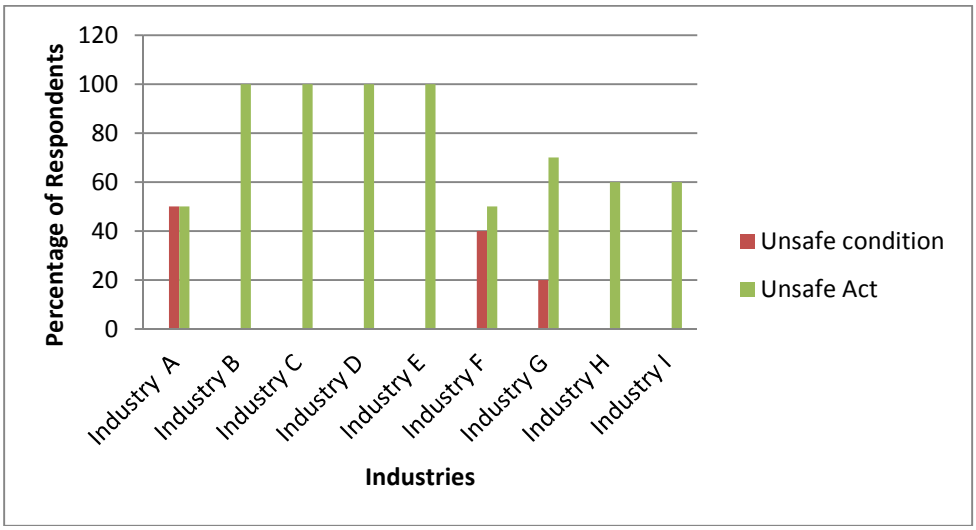

Fig. 2: Causes of Accident

It can be deduced from Table 2.0 that the cost incurred by the occurrence of accident on the industries for a period of ten years according to accident class was shown on Table 2.0: it was observed that the cost incurred due to serious accidents were high compared to that incurred by minor accident, though the rate of minor accidents were more than the serious ones. Also, a notable observation was that no fatalities experienced or recorded. Despite, there is more room for

improvement, most especially in safety culture,planning and management. More so, deductions from results of availability, reliability and maintainability as shown in table 1.0 and total costs of accidents in all the study areas as shown in table 2.0 reveals that reliability , fatalities and cost of accidents are interconnected. Company G has lowest reliability with highest cost of serious accidents of # 1,256,648,599.

Table 2.0: Overall Economic Implication of Accident for a Period of Ten Years

Industry	Accident Class	Average number of each class of accident	Total Cost of Accident (Naira)
A	Minor	9	308,929,788
B	Serious Minor	7 10	472,748,724 1,105,578,583
C	Serious Minor	6 6	1,257,719,150 394,948,045.5
D	Serious Minor	9 4	1,182,147,068 234,822,785.7
E	serious Minor	2 12	234,391,392.9 596,244,649
G	Serious Minor Serious	10 8 9	978,050,598.2 559,420,955.7 1,256,648,599

CONCLUSION

The following conclusion can be drawn from this study

1. The Maintenance, safety culture, planning and management in manufacturing industries is still not as adequate as expected. This should be improved in order to ensure waste reduction, reduction in operational cost, increased productivity and efficiency.
2. Four major factors identified to be responsible for maintenance challenges were: Excess workload, failure of parts, untrained operator and inadequate maintenance.
3. Accidents occurred majorly due to unsafe acts and safety culture of an organization as a result of lack of compliance to safety rules by the workers, defective safety policies and practices by the management as well as appropriate safety legislation by the government or its agencies saddle with the responsibility.
4. Workers do not undergo continuous training on maintenance practices. It was also observed that they were not dynamic in their training and practices.
5. It was observed that much emphasis was not on Safety across all the companies and estimated accident costs were superfluous based on accident class. Serious accident cost recorded was much more than that of minor despite minor accidents having higher rate.

RECOMMENDATION

1. Maintenance practices in manufacturing industries should be improved upon in order to increase and improve productivity thereby maximizing profit.
2. There is a need to develop a more effective and efficient maintenance and safety programme in manufacturing industries.
3. Trainings on workplace safety should be organized for workers from time to time so as to provide workers with good knowledge on safety practices thereby preventing the occurrence of accidents due to unsafe act and condition.

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