International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 10 (2019), pp. 1654-1663

Six Sigma Approach in Safety Management of a Production Firm

T. O. Kehinde[1,*], A. E. Oluleye[2,*], K. J. Olaleye[3], S. L. Jegede[4]

[1,2]Industrial and Production Engineering Department, University of Ibadan, Nigeria.

[3] Department of Metallurgical and Materials Engineering, Federal University of Technology Akure, Nigeria.

[4]Research and Statistics Department, Landmark University, Omu Aran, Nigeria.

[1]ayodeji.oluleye@mail1.ui.edu.ng; [2]kehindeolubanjo@gmail.com [3]Olaleyekayode1992@gmail.com, [4]jegede.segun@lmu.edu.ng

ORCIDs: 0000-0001-7703-7395(T. O. Kehinde), 0000-0003-2780-5290(A. E. Oluleye)

0000-0003-4514-6962(K. J. Olaleye), 0000-0002-9973-1377(S. L. Jegede)

Abstract

The rate and effects of accidents in Nigerian Production/Manufacturing industries are quite debilitating and consequently need mediation. The study appraised the safety programme of a food processing company XYZ with the aim of applying the Six Sigma methodology for improving safety. Evaluation of safety practices and investigations were made through collected data, safety reports, oral interviews and personal observation of the working environment. Six Sigma approach was introduced using all the five phases of DMAIC method. Using this methodology, the most critical hazard; Environmental effect (extreme cold environment) of Risk Priority Number (RPN) 729 was identified and also, the current sigma state of the company was estimated to be 4.96 which is quite satisfactory but not the desired state of maximum safety. Concentration on elimination of hazards by the management is recommended. Also, an estimated cost of ₦683,457.50 tocontrol the long term effect of noise which is prevalent at all workstations in the factory was arrived at. With the Cost effectiveness index of 45.51, the management can safely embark on the investment with assurance of full benefits coverage. By way of adoption and implementation of this approach, the Sigma level is expected to rise continuously.

Keywords: Six Sigma, Safety, Accidents, Hazard.

1.0 INTRODUCTION

Five major factors have been found to be directly associated with the potential causes of accidents viz. psychological, environmental, ergonomic, physical, and stress (Sherry, 1992). In spite of various Safety policies being adopted, occupational injuries still plague our manufacturing, production and construction industries (Kines *et al*., 2013) and their impacts are so great that consequences in high-risk industries may be disastrous (Lind, 2008, Ciarapica and Giacchetta, 2009). However, the effects of accidents are seen in loss of lives, equipment, man hours, raw materials, capital as well as high medical cost, compensation cost and emotional losses. There are many approaches to improve workforce safety in manufacturing/production amongst which are ergonomics, Safety Incentive Programme (SIP), Behaviour Change and Culture Change Approach, Building Information Modelling (BIM), Adaptive Management, Foucauldian Approach and Safety Climate. Despite the persistent endeavours to promote manufacturing safety, fatalities still plague the industries and absolute safety of humans and property remains an illusion (Adebiyi and Ajayeoba, 2015).

1.1 RESEARCH OBJECTIVES

The research objectives are:

a. To appraise the safety programme in the selected organization.
b. To use Six Sigma approach to measure, analyse and improve the safety plan of the organization.

1.2 JUSTIFICATION

In order to deliver excellence in safety performance, the implementation as well as management of safety programmes needs to be constantly assessed and evaluated for effectiveness. It is the common interest of everyone to have a safe and healthy workplace. However, the role each person is willing to play, in order to accomplish this, varies a great deal. The safety manager or industrialist hygienist is usually charged with the safety and health programme within a firm. A good safety management, if adopted, would avail the management of a particular firm the opportunity to measure, analyse and improve overall safety plan, consequently ensuring the protection of life and preservation of health of the workforces to an acceptable optimal level. It is therefore the problem of this study to appraise the present safety programme in the organization and also introduce an alternative approach known as Six Sigma methodology.

2.0 LITERATURE REVIEW

Safety is defined as a condition where nothing goes wrong or a condition where the number of occurrence of accident, risk of injury, loss and danger to persons, property and environment is acceptably small (Hollnagel, 2014). Thus, Safety is said to be driven by simple principle of complete elimination of technical breakdowns and human errors (Rene, 2017). Also, it is worthy to note that appraisals are not limited to establishing wrongs and shortcomings; they determine the overall status quo of the system. The primary aim is not to manifest errors present thereof, but to descry issues which act as impediment to the smooth running of the activity, as well as hinder the effective accomplishment of established goals

2.1 THEORIES OF SAFETY

There are various theories of safety in existence and this include Heinrich's theory, System theory, Scientific management approach, Case study approach to safety etc.

Heinrich (1959), proposed in his theory that 88% of accidents stemmed from "unsafe acts," while 10% were the aftermath of "unsafe conditions". This gives a total of 98% measured to be evitable, with the remaining 2% was considered inevitable and consequently, justifies the need for management to pay more attention to unsafe practices of workers in the construction industry (Mingyu*et al*., 2014). He further by stating that for an accident to occur, factors such as ancestry/social environment, fault of individual, unsafe act, mechanical/physical hazard, the accident and the injury must be present.

A Systemis a collection of interactive and organised components which, together, form an integrated entity. System theory relates to studying a scenario in which an accident may befall as that comprising components such as persons (host), machines (agency), and environment. Figure 2.1 shows a representation of a system model together with its components.

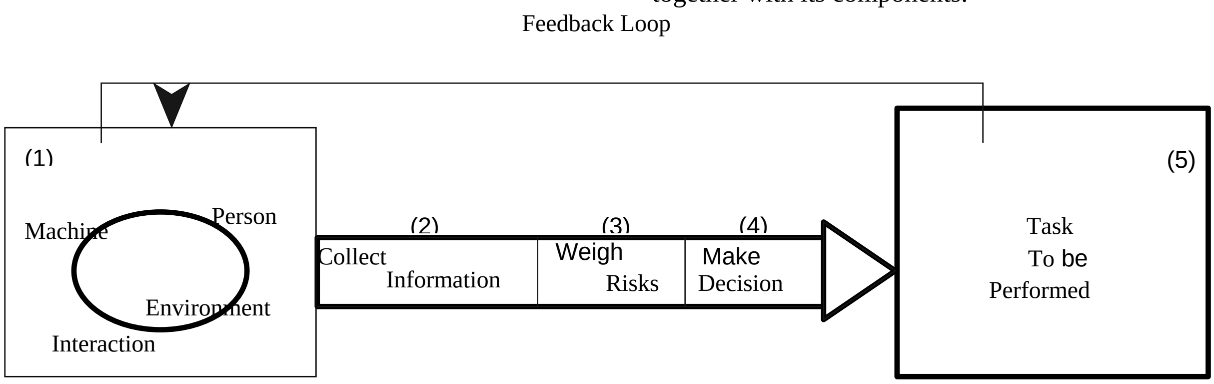

Figure 2.1: Representation of a system model.
Source: Goetsch (1998).

In respect to efficiency, a logical objective of scientific management is toward the improvement of health and safety. Albeit, Frederick Taylor, the founder of scientific management proposed a theory of ensuring maximum labour productivity while paying negligence to the negative effect it has on workers' (Richard and Uday, 2007). Nonetheless, the correlation between 'scientific management' and ' workers health' cannot be overemphasised, and it is germane to the geneses of modern health and safety management systems. Two phases represent the core of this association. First, practitioners of scientific management did regard health and safety as a matter of great importance, although in a limited way. The second phase of the association is pronounced in the impact of scientific management and the corresponding outcome on the improvement of health and safety programme.

Case study research (Sohal, 1996), field study guidelines and binary variable were used in gathering data from 36 companies. Data analysis was done using mean, percentage and standard mathematical models. At the end, 'minor accidents' recorded the highest frequency of incidence, with 'fatal accidents' logging the least, and 'serious accidents' having the greatest economic implication. In addition, standard working procedures, tidying and on-the-job training are notably being adopted while availability of safety handbook and program is least practised. The methodology as summarized by Curtain *et al*. (1992), following Stoecker (1991), are able to establish the strengths and weakness of using this approach. The strengths include;

i. Elucidating complex systems and explaining the cause and effect of association between variables.
ii. Studying of a system in a wider context.
iii. Supporting in-depth analysis in order to uncover new theoretical acumens and ideologies.

However, its drawbacks include:

i. The incompetence of such model to expatiate from cases to the larger population.
ii. There may be unfairness in the interrelation between the researcher and the case study subjects.
iii. There may be scenarios for collection of data that are cumbersome and seem incomparable.

2.2 SAFETY AND PRODUCTIVITY

Umoh and Lezaasi (2013), confirmed that, not only do accidents reduce productivity, they also spike up the cost of production. They classified this into direct and indirect costs. The direct costs include medical fees, compensation / insurance cost, death benefits, wage lost etc., while the indirect costs include loss of time, damage to machineries and equipment, replacement of injured employees etc.

The study showed that the relationship between the provision of adequate safety equipment and the work output of employees has a Spearman's rank correlation coefficient of 0.80; The relationship between legal institutional safety policies and the production outputs of employees has a

Spearman's rank correlation coefficient of 0.60; The relationship between employer's compliance to safety rule and man hour put in by employees in the production process has a Spearman's rank correlation coefficient of 0.70. The results proved that the relationships are significant and expedient to ensure a safe working environment and maximum productivity of workers.

2.3 SIX SIGMA (6σ)

In 1987, Motorola introduced the Six Sigma technique. Their primary aim was to reduce process output variation so that six standard deviation lie between the mean and the nearest specification limit (Lateef, 2012). Using this approach, it was found that, in a lot of one million opportunities, 3.4 defects (per million) are acceptable (Senthilkumar and Esha, 2015). Multinational and International companies like Dufil Prima, Sidel, Airtel, Honda motors, JK tyres, British Airways, ICICI Bank, Microsoft, Indigo Airlines and many more now uses Six Sigma as an improvement tool in their operation processes. Management commitment to ensuring safe practices is a veritable way of entrenching a safety culture (Sasikala and Saravaran, 2011). Table 2.1 shows the standard sigma level with their corresponding defect values.

Table 2.1 Six Sigma Process Capability vs. Defects Per Million Opportunities.

Sigma	DPMO
1	697672
2	308770
3	66811
4	6210
5	233
6	3.4

Source: Quality American Inc. (2018)

3.0 METHODOLOGY

For this study, XYZ is a food company that is involved in processing of milk based and water based product such as Vanilla yoghurt, Chocolate yoghurt, Super yoghurt, Ice cream and Fruit juice. XYZ was selected due to the high rate of severe and fatal accidents experienced in the factory. XYZ has a safety committee which comprises of 14 safety representatives that cut across all departments headed by Environment, Health and Safety (EHS) manager. XYZ has its own safety programmes which include EHS, safety posters, hygiene and health practices but, the programme is neither effective nor efficient enough as the programme practices failed to reduce high rate of accidents to a bearable minimal. The techniques adopted in the course of this investigation include Use of questionnaire survey, Personal observation of the working environment, Oral interviews and Records viewing.

3.1 SIX SIGMA METHODOLOGY

The central idea behind Six Sigma is to measure the quantity of "defects" in an operation and then, reduced them. The methodology can be applied in preventing accidents and thus, enhancing safety. However, the interpretation and application of DMAIC (define, measure, analyse, improvement and control phases) method using all the 5 phases of Six Sigma are elaborated below.

3.1.1 Define Phase

The define phase is meant to do safety evaluation and collection of data of the selected firm. This will be duly presented using a bar chart that shows the distribution of accidents per month and also the department wise split of accidents. Data is collected and managed. Moreover, hazards identification and common injury types in the company are also evaluated for effectiveness.

3.1.2 Measure Phase

The measure is concerned with the data collection in relation to accidents in the establishment. Furthermore, it gives the statistical organisation and Sigma level calculation of the establishment contingent upon the data used. The data required for Sigma level goes thus;

i. Unit = Employee
ii. Defect = Employee Recordable injury or illness
iii. Opportunity for error in unit = 1/workday
iv. Assumption: 250 workdays per year =250/year
v. Defects per unit (DPU) = Total defects/Total units Defects Parts per Million (ppm)
vi. Defects parts per million (PPM) = (DPU/Year*1000000)/Opportunity for error in 1 unit

It is worthy to note that Excel Formula or Sigma Table can be used in converting PPM to Sigma State. However, Sigma level will be calculated using a formula on Microsoft Excel'13 software in order to have a more precise value than the one gotten through interpolation of data on Sigma Table.

3.1.3 Analyse Phase

In this phase, data is collected, statistically represented, and then analysed in order to generate the recommended solution, thereby ensuring the improvement of Sigma State. FMEA is a tool used for in depth investigation of industry performance and productivity growth. It shows the functional process, failure types, occurrences, severity of defect and recommended actions to be taken. Safety is a function of risk priority number, the higher the Risk Priority Number (RPN), the lower the safety. Therefore it is imperative that this number is reduced to the best minimum.

3.1.4 Improvement Phase

The phase is concerned with identifying various hazards found at various workstations in a bid to eliminate them. The appropriate solutions are consequently proffered in order to ensure a safe working environment.

3.1.5 Control Phase

This phase provides a control check for the solutions proffered at the improvement phase. A control sheet is normally designed to serve as a means of evaluating safety conformance and performance.

4.0 DATA COLLECTION AND ANALYSIS

The company under consideration has 602 workers with over 300 of them working in the production department that operates on 8 hours per shift and 3 shifts per day. The Production department has 8 workstations that engage in the processing and packaging of various products with the use of several automated machines such as DJ, TCA, TBA, IS6 prepac, Scanstore, Hillerslev machine etc. However, the use of these machines have their own hazards and the likelihood of causing accidents.

4.1 DEFINE PHASE

The data of severe accidents that took place at XYZ for the period of January to December 2014 were collated. However, it was observed that the Production department had the highest number of accidents and this justified the focus on the Production department. Bar charts as presented in Figure. 4.1 and Figure. 4.2 were used to show the accidents statistics for the year 2014.

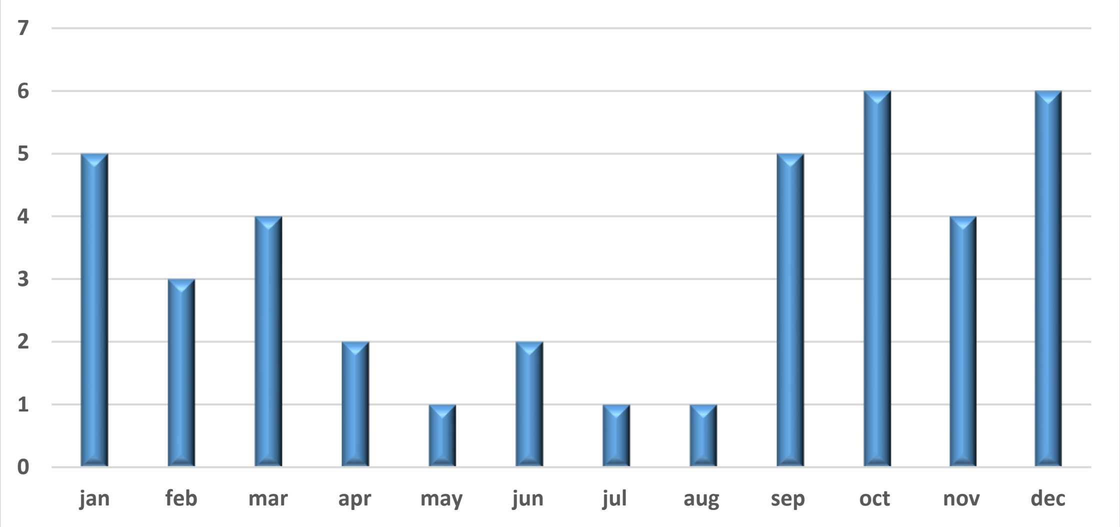

Figure 4.1 Monthly Distribution of Accident Statistics for the Year 2014

Source: XYZ

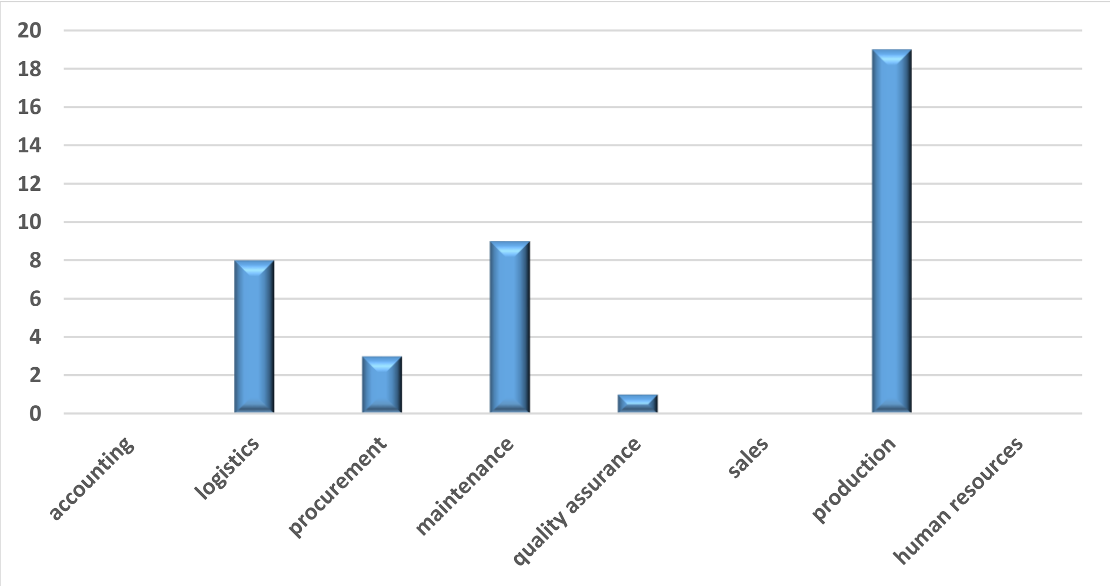

Figure 4.2: Department Wise Split of Accidents for the Year 2014

Source: XYZ

Noise is virtually being experienced at all workstations. Noise Level Meter was used in measuring the intensity of noise in decibel (dB) at various workstations. The readings were taken at two different shifts (morning and afternoon). The result is hereby presented in Table 4.1.

Table 4.1 Noise Intensity at various workstations.

S/N	Workstations	Noise Level (Mrn Shift) dB	Noise Level (Aft. Shift) dBb	Average Noise Level (dB)
1.	TCA Unit	89.6	91.8	90.7
2.	TBA Unit	89.1	91.3	90.2
3.	KCRP Freezer Unit	95.4	98.8	97.1
4.	Ice Cream Unit	92.3	93.5	92.9
5.	Hill. and Scan. Unit.	98.5	90.7	94.6
6.	DJ and IS6 Prepac Unit	91.9	93.7	92.8
7.	Pet Bottles Unit	117.8	119.2	118.5
8.	Round Table Unit	90.2	93.4	91.8

Consequently, the high level of noise being experienced at various workstations can be considered hazardous because their results being greater than 85dB could either lead to temporary or permanent deafness in which surgery may not help correct this type of hearing loss (OSHA, 2010).

4.1.1 Hazards Identification

From general observation, investigation, and documentation of the safety reports received, the unsafe acts or conditions of XYZ were been able to be classified according to the following.

Class A: Work Environment

The condition that will cause accident or ill-health in a work environment includes:

1. Noise and vibration from machines or plants which ranges 89.1-119.2 decibels.
2. Explosion of steam pipes.
3. Contact with chemicals e.g. caustic soda, hydrogen peroxide, and oxonia.
4. Extreme coldness (below 10oc).
5. Fire outbreak due to raw materials like cartons.
6. Contact with hot surfaces e.g. Hot water pipes.
7. Slippery floors due to milk spillage.
8. Obstructed fork lift and jerking truck path.
9. Obstructed entry, exit and passage.
10. Falling of object or operator from height.
11. Extreme warmness (Pet bottles unit).

Class B: Work Method

The conditions that will cause accident adapting any work method may include the following:

1. Working without complete personal protective equipment (PPE).
2. Working without guards in their positions.
3. Working in a confined area without regular supervision.
4. Working with bad posture.
5. Working in a non-ergonomic manner.
6. Repairing, Mounting and dismounting from moving or working equipment.
7. Handling of products unsafely.
8. Compulsory overtime work.
9. Using ladders with unbalanced legs.

Class C: Parts of Operating Machine

The conditions that will cause accidents by any parts of operating machine are:

1. Lower and upper jaws of machines parts.
2. Electrode or heating element.
3. UV-Light.
4. Loose screws, nuts, bars, studs or moving parts.
5. Machines steps without railings.
6. Valve explosion.
7. Hot water pipes for cleaning-in-place (CIP) process.
8. Loose conveyor or moving belt.
9. Pinch points of machine parts.
10. Unguarded machine parts.

Class D: Worker

Accidents are caused here due to the followings:

1. Use of tools or equipment in unsafe ways.
2. Use of defective tools or equipment.
3. Poor work habit and attitude.
4. Insufficient skills.
5. Use of hand instead of tools.
6. Horse play.
7. Failure to use personal protective equipment.

Also, table 4.2 shows the different workstations in the Production department and the cumulative hazards found based on analysis.

Table 4.2 Workstations and their cumulative hazards.

S/N	WORKSTATIONS	CUMULATIVE HAZARD
1.	TCA Unit	16
2.	TBA Unit	17
3.	Ice Cream Unit	22
4.	KCRP Freezer Unit	18
5.	Hillerslev and Scanstore Unit	22
6.	DJ and Prepac IS6 Unit	28
7.	Pet Bottles Unit	9
8.	Round Table Unit	12

4.2 MEASURE PHASE

At the measure phase, the current Sigma level of the company is calculated.

Calculation of Sigma Level of the Current State of the Company:
Unit = 602 Defect = 40
Opportunity for error in unit = 1/workday
Assumption: = 250days/year DPU = 40/602 = 0.0664/year
Defects parts per million (PPM) = (0.0664/year x 1000000) / (250/year) = 265.5 PPM
The procedure in getting the Sigma Level as adopted from Quality American Inc. (2018) using Microsoft Excel'13 goes thus.

Step 1: open the excel sheet.
Step 2: enter the PPM value i.e. 265.5 in cell A1 of the excel sheet.
Step 3: enter 1,000,000 in cell A2.
Step 4: use the formula below in cell A3 to obtain the value 0.0002655

$$= \frac{A1}{A2}$$

Step 5: enter the formula = (NORMSINV(1-$A3))+1.5 at cell A4. = 4.96461

The methodology of Six Sigma as applied to company XYZ under consideration is estimated to be 4.96 which is quite satisfactory but the goal is to reach Sigma state of 6.0. However, this can be achieved by tackling the inherent challenges of hazards found at various workstations.

4.3 ANALYSE PHASE

In a bid to scale up system performance and attain higher Sigma Level of operations, Hazard analysis is carried out with the aid of Failure Modes and Effects Analysis. Table 4.3 shows the FMEA analysis of identified operations and processes. Symbol S means Severity, O means Occurrences, and D means Detection and RPN means Risk Priority Number.

Table 4.3 Failure Modes and Effects Analysis of operations and processes at FMP.

S/N	Function Process	Failure Type	S	O	D	RPN	Recommended Action
1.	Improper handling (using bare hands)	Shivering of hands	4	8	4	128	Use of good and quality hand gloves
2.	Improper Stacking of finish products	Falls of container containing products	5	5	5	125	Only jumbo containers with balance legs should be used.
3.	Work method	Back and waist pains.	9	8	7	504	Use of ergonomic design stood and other equipment
4.	Environmental effect (Noise)	Temporary deafness	7	10	6	420	Sound proof or silencer for all the machines. Use of ear muffs or plugs by all workers
5.	Environmental effect (Extreme cold environment)	Chest pains, muscular weakness, drowsiness, cardiovascular problem etc.	9	9	9	729	Protective cloth should be cold proof. Hot water bathe should be made available for workers.
6.	Environmental effect (Extreme heat environment)	Heat stroke, thirst, hyperthermia, heat edema, heat cramps, hallucin etc.	9	8	9	648	Wear light coloured loose fitting clothes such as cotton. Cold water bathe should be made available for workers.
7.	Fork lift and Jerking trucks Path	Accidents occur due to insufficient technical skills of driving. Congested work area.	8	4	4	128	There should be a clear and defined path for fork lift. Only skilled workers should be allow to drive forklift.
8.	Workers negligence to safety	May create dangerous and hazardous problems to them.	6	7	6	252	Awareness programmes, routine training and adequate supervision of employees.
9.	UV-Light	Irritation and eye aches.	5	5	9	225	The UV- light should have sensor that can automatically switch off when exposed.
10.	Unguarded machine parts	Electrocution, bruises, cut and death etc.	7	8	7	392	Machine parts should be guarded.
11.	Slippery floors due to milk spillage.	Arm fracture, cut, leg fracture, etc.	4	7	4	112	Hygiene should be maintained at all times.
12.	Cleaning in progress (CIP) operation.	Burns due to Splashing of caustic soda and Oxonian.	7	6	8	336	Precautions should be duly followed in cleaning process
13.	PPE	Chest pain, shivering and cardiovascular related problems.	10	8	5	400	Safety checklist should be used before operations are carried out.
14.	Manual carrying and lifting of LLDPE (foil wrapper555)	Work Musculoskeletal Disorder. Back And Waist pains	5	4	7	140	Hoist should be provided and used for such operation.

4.4 IMPROVEMENT PHASE

This phase elaborated more on how to individually tackle each problem found in the FMEA table by preferring the appropriate solution, thereby achieving high safety standard. The table 4.4 shows the various safety problems and their recommended solutions.

Table 4.4 Safety problem and their recommended solutions.

S/N	PROBLEM	SOLUTIONS
1.	Improper handling of frozen products.	Good and quality hand gloves should be provided.
2.	Improper Stacking of finish products	Only jumbo containers with balance legs should be used.
3.	Work method	Ergonomic design of facilities in the production factory. There should be reward for safe behaviours
4.	Environmental effect (Noise)	Use sound proofs for machines. Workers should be provided with ear muffs or ear caps.
5.	Environmental effect (Extreme cold environment)	Protective cloth should be cold proof. Provision of bath room to have warm water bathe at a regular interval of 2 hours.
6.	Environmental effect (Extreme heat environment)	Wearing protective light clothes made of cotton material. Four heat extractors instead of two should be provided at the Pet bottles unit so as to maximise heat loss
7.	Fork lift and Jerking trucks Path	There should be a clear and defined path for fork lift and jerking truck movement. Only skilled workers should be allow to drive forklift.
8.	Workers negligence to safety	Heavy fines should be imposed on the affected workers. Awareness programme and routine training of employees to ensure conformance to safety standards.
9.	UV-Light	The UV- light of DJ F/F/S machine should have sensor that can automatically switch off when exposed. Use safety goggle to avoid direct contact with UV-light.
10.	Unguarded machine parts	Machine parts should be guarded. Blades used for cut-off should have only one cutting edge.
11.	Slippery floor due to milk spillage.	Hygiene and cleanliness should be maintained at all times. Floors should be mobbed at periodic intervals.
12.	Manual carrying and lifting of LLDPE (foil wrapper).	Hoist should be made available and used for such operation.
13.	Cleaning in progress (CIP) operation.	Precautions should be taken while working. First aid box should be provided close to operation centre.
14.	Inadequate PPE	Management should provide adequate PPE such as safety boots, hand gloves, nose cover, hair net, helmet, apron etc.

Noise is an undesirable input in a system which inevitably affects employee health and performance on the job. It is therefore, justifiable that the management should provide means of eliminating this hazard inherent at all workstations in the production department. The estimation of recommended hearing protection devices and their purchase cost gotten through market survey at various online stores are given below and summarized in Table 4.5.

Name of device recommended for Pet Bottles Unit: High Quality Electronic Earmuffs Soundproof (device is reusable and washable).

Name of device recommended for other Units (except Pet Bottles Unit): Blue Safety Soft Jelli Ear Plugs Hearing Protection Muffs (device is reusable and washable).

Total number of workers at XYZ = 602

Total numbers of workers in the Production department = 311

Conversion rate as at 30-09-2018.

$1 = 362.5
Source (https://fx-rate.mobi/USD/NGN), 30th September, 2018

Table 4.5 Cost estimation of Ear muffs and Ear plugs

Device	**EAR PLUG**	**EAR MUFF**
Number of Hearing protectors required	284	27
Extras to be bought	20	7
Total Number Required = Number of Hearing protectors required + Extras	304	34
Noise Reduction Rating (NRR)	24	30
Cost per piece	$2.10	$8.95
Total Cost	304 * 2.10 = $638.40	34 * 8.95 = $304.30
Total Cost in Naira	638.40 * 362.5 = ₦231,420.00	304.30*362.5 = ₦110,308.75

Purchase Cost = ₦231,420.00 + ₦110,308.75 = ₦341,728.75

NB The hearing protections are meant to be used and disposed after six months i.e.

2 hearing protection device/worker/year

Therefore, **Total Purchase Cost (Expenses) to be budgeted by the management/year**= ₦341,728.75 * 2 = ₦683,457.50/year

The cost of ₦683,457.50/year will help to mitigate the risks and effect of Noise on all workers in the Production department.

Table 4.6 shows the expected reduction as a result of buying and using the recommended hearing protectors

Table 4.6 Expected Reduction in Noise Level.

S/N	**Workstations**	**Current Noise Level (dB)**	**Reduction caused by Noise Control Aids (dB)**	**Expected Noise Level (dB)**
1.	TCA Unit	90.7	24	66.7
2.	TBA Unit	90.2	24	66.2
3.	KCRP Freezer Unit	97.1	24	73.1
4.	Ice Cream Unit	92.9	24	68.9
5.	Hillerslev and Scan –Store	94.6	24	70.6
6.	DJ and IS6 Prepac Unit	92.8	24	68.8
7.	Pet Bottles Unit	118.5	30	88.5
8.	Round Table Unit	91.8	24	67.8

It is expedient to make a cost recovery analysis in order to know when the company expenses on hear protections will recoup its costs and at what proportion and number of workers will the cost breakeven. However, the average cost of Ear related treatment gotten through consultations from various ENT (Ear, Nose and Throat) medical specialists and consultants in Ibadan gave the following cost estimations.

Average cost of treatment for temporary hearing loss/patient = ₦30,000.00

Average cost of treatment for permanent hearing loss/patient = ₦170,000.00

Average cost of treatment of hearing loss= (₦30,000.00 + ₦170,000.00)/2= ₦100,000.00/patient.

Number of XYZ Factory workers (Production department) = 311

Cost Recovery ratio = $\frac{Expenses\ (Purchase\ Cost\ of\ Hearing\ Protection\ Devices)}{Unit\ \ Treatment\ Cost\ Saved} = \frac{683457.5}{100000}$ = 6.834

This implies that the equipment investment cost is covered by savings from treatment costs of 7 workers.

Therefore, Cost effectiveness can be expressed as:

Cost Effectiveness Index = $\frac{Total\ number\ of\ Workers\ covered\ by\ equipment\ Investment}{Cost\ Recovery\ ratio} = \frac{311}{6.834}$ = 45.51

This result indicates that the equipment investment is very well covered by the benefits accruing from savings in treatment costs.

International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 10 (2019), pp. 1654-1663

The results show that the purchase of the hearing protection devices for all workers will mitigate the effects of noise on all workers. The investment is fully recovered making the intervention cost effective.

4.5 CONTROL PHASE

A control sheet for monitoring the factory safety on a daily basis was developed and this is duly presented as a control chart as shown in Table 4.7

Table 4.7 Table of Control Chart.

CONTROL SHEET FOR SAFETY

Name of Establishment: XYZ. **Date of previous inspection: ______________________________**

Department: Production department **Date of inspection:_______________________________________**

REMARK: In Order i.e. OK √ **Not Order i.e. Need attention** X

S/N	**PROBLEMS**	**Remark**	**Comments**
1.	Ventilation of the Pet bottle plant		
2.	Cleanliness and Sanitation of work area		
3.	Room temperature of the Pet bottle unit.		
4.	Room temperature of the ice cream unit.		
5.	Room temperature of the DJ and IS6 Prepac unit.		
6.	Operators' compliance with safety instructions.		
7.	Handling method at KCRP unit.		
8.	Equipped first aid box at all operation centres or workstation		
9.	Good posture of workers while working		
10.	Ladder condition		
11.	Machine parts condition		
12.	Provision and use of PPE		
13.	Path for fork lift trucks and jerking trucks.		
14.	Condition of Jumbo containers.		
15.	Free and clear emergency exits		
16.	Skilfulness of workers		
17.	Noise level at all the workstations		

PREPARED BY:_____________________ (Name of Safety Officer) Signature:____________________

CHECKED BY: _____________________ (Name of Safety Manager) Signature:) ___________________

5.0 SUMMARY AND CONCLUSION

The study appraised the safety programme of a food processing company XYZ with the aim of applying the Six Sigma methodology for improving safety. Evaluation of safety practices and investigations were made through collected data, safety reports, oral interviews and personal observation of the working environment. . The production department of the company had the highest percentage of the total accidents occurrence. The safety Sigma level was estimated to be 4.96 which is quite satisfactory but not the desired state of maximum safety. The most critical challenge; Environmental effect (extreme cold environment) of RPN (Risk Priority Number) 729, was identified. Concentration on elimination of hazards by the management is recommended. Also, an estimated cost of ₦683,457.50 was arrived at to control the effect of noise hazard being experienced at virtually all workstations. With the Cost effectiveness index of 45.51, the management can safely embark on the investment in equipment with assurance of full benefits coverage. By way of adoption and implementation of this approach, the Sigma level is expected to rise continuously.

REFERENCES

[1] **Adebiyi, K.A. and Ajayeoba, A.O. (2015),** Integrated Modelling of Manufacturing Safety Interventions Planning and Management. Paper presented during International Conference on Aeronautical and Manufacturing Engineering (ICAAME'2015) March 14-15, 2015 Dubai (UAE).

[2] **Ciarapica, F.E. and Giacchetta, G. (2009),** Classification and Prediction of occupational injury risk using soft computing techniques: An Italian study. Safety Science 47 36-49.

[3] **Curtain, R., Gough, R., and Rimmer, M. (1992),** Progress at the Workplace: Workplace Reform and Award Restructuring, AGPS, Canberra.

[4] **Goetsch, D. L. (1998),***Implementing Total Safety Management* (Upper Saddle River, NJ: Prentice Hall, 1998), 227.

[5] **Heinrich, H.W. (1959),** Industrial accidents prevention: a scientific approach, 4th edition, McGraw-Hill

[6] **Hollnagel, E. (2014),** "Is Safety a Subject for Science?", Journal of Safety Science, vol 67, pp 21-24.

[7] **Kines, P; Andersen, D; Andersen, L.P; Nielsen, K. and Pedersen, L. (2013),** Improving safety in small enterprises through an integrated safety management intervention. Journal of Safety Research 44, 87-95.

[8] **Lateef, R.A. (2012),** a scientific research work on "Safety Management in a Manufacturing Company: Six Sigma Approach". http://www.SciRP.org/journal/eng.

[9] **Lind, S. (2008),** Types and Sources of fatal and severe non-fatal accidents in industrial maintenance. International Journal of Industrial Ergonomics 38, 927-933.

[10] **Mingyu, S., Hyun-Soo, L., Moonseo, P., Myunggi, M., Sangwon, H., (2014),** "A System Dynamics Approach for Modelling Construction Workers", Journal on Accident Analysis and Prevention, vol. 68, pp 95-105.

[11] **Occupational Safety and Health Administration (2010),** http://www.osha.gov/SLTC/noisehearingconservation.html, retrieved on 11th November, 2015.

[12] **Quality American Group (2018),** http://qualityamerica.com/LSS-Knowledge-Center/leansixsigma/converting_dpmo_sigma_level.php , retrieved on 11th November, 2018.

[13] **Rene, A. (2017),** "The Paradoxes of almost Totally Safe Transportation Systems", Journal of Human Error in Aviation, pp 101-118.

[14] **Richard, B.C. and Uday, M.A. (2007),** "A History of Research in Service Operations: What is the Big Idea", Journal of Operations Management, vol 25 (2), pp 375-386.

[15] **Sasikala, A. and Saravaran, S.P.B (2011),** Six Sigma and Employees safety – A novel Approach, Int. J. of Operations Systems and Human Res. Mgt., Vol. 1. No. 1-2, pp 1 -14.

[16] **Senthilkumar, D. and Esha, R.B., (2015),** "Construction and Selection of Six Sigma Quick Switching Sampling Systems: Sample Size Tightening", Journal of Innovation Research in Computer and Communication Engineering, vol.3, pp 1410-1418.

[17] **Sherry, P. (1992),** "Peer Involvement and Behavioural Safety." www.du.edu/~psherry/hav.html.

[18] **Sohal, A.S. (1996),** "Assessing AMT implementations: an empirical field study", *Technovation,* vol. 16 No. 8, pp. 377-384.

[19] **Stoecker, R. (1991),** "Evaluating and Rethinking the Case Study" in the Sociological Review, 31 (1), pp 88-112.

[20] **Umoh, G.I. and Lezaasi, L.T. (2013),**International Journal of Business and Management Review, Vol.1 No 3, pp. 128-137, September 2013. Published by European Centre for Research Training and Development UK (www.ea-journals.org).