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Evaluation of safety practices and performance in a brewery industry in Nigeria between 2000 – 2007

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ABSTRACT: Safety practices and performance in a brewery industry in Nigeria was evaluated for a period of eight years between 2000 – 2007 using the principles of statistical expectation and efficiency index. The number of prevented accidents and the corresponding values of lives and property saved were estimated annually for the same period of eight years. The type of input resource, total number of input resources, total number of prevented accidents by class, the unit cost of each of the accident class, the cost of input resources, quantity of each type of input resources and the targeted period were identified. The study revealed that a total of 156 accidents were prevented in the period of the safety programme which translates to an average of 19.45 per year. The safety programme also saved lives and property worth ₦ 20.2 million for the eight year period which is at an average of ₦ 2.5 million annually. The computation of efficiency indices due to the use of all the input resources when compared with the standard period and it was discovered that all the resources were well utilised. The significance and benefits of the work to the local community and other industries is that the principles of statistical expectation and efficiency index can be easily applied to analyse the performance of safety programme in the industries. @JASEM

An accident is an unplanned, unexpected, and undesigned (not purposefully caused) event which occurs suddenly thereby causing injury or loss, a decrease in value of the resources, or an increase in liabilities. Virtually, everyday and in every human endeavour, accidents have become a regular feature. It occurs in human endeavours such as transport, homes and manufacturing organisations among several others. They most often occur as a result of unsafe conditions of work (Adebiyi et al, 2007). These undesirable events may lead to human injury, damage to property, and loss of production hours, disease, permanent disability or death, (Duignan, 2003 and Burns, 2006). The consequences of accidents, in some cases, are not borne only by those directly involved but extended to relatives, friends, employers and government (Adebiyi, 2006). Despite all established standards and legislations on safety, with sophisticated devices developed and researches carried out (Adebiyi et al, 2005); yet, a perfectly safe condition for human and property is still an illusion.

The desire for safety is on the increase in the manufacturing industry. Apart from the cost due to downtime, loss of wages and equipment, hospitalisation, the tragedy associated with personal injury, disability and fatality is enormous. As far as fatalities are concerned, industrial accidents take the third place after vehicle and homicide, (Duignan, 2003 and Adebiyi, 2006). In Nigeria, the manufacturing sector has stagnated, and its contribution to GDP and employment remain small, due to "weak safeguards against occupational and other hazards" (Adebiyi et al, 200). Although, this is one of the factors that is responsible for the stagnation, also abound are the problems of unstable electricity power supply, harsh government policy and lack of favourable enabling environment. In one of the reports of the Nigerian Institute of Safety Professionals (NISP) over 11,000 people die from on-the-job accidents each year and a worker is injured every 18 seconds in chemical industries in Nigeria. Adebiyi (2006) reported that there is higher incidence of fatal work-related injuries in developing world than in the developed ones.

The problem of appropriately quantifying human life is the major problem of costing accident and no generally accepted model has been developed for this. There is need to provide useful mathematical tool to assist in taking judicious decisions concerning safety in our industries. This study investigates the performance of safety programme of a brewery firm for a period of eight years: from 2000-2007. Specifically, the number of prevented accidents, the corresponding lives and property saved and the way resources were used to achieve such safety were investigated.

MATERIAL AND METHOD

Safety programme performance can be examined by considering the losses and costs associated with accidents and safety programme. The efficiency of a safety programme is related to how much of these losses are reduced or eliminated. The inputs are the resources used to run such a programme. The principles of statistical expectation and efficiency function can be used to analyse the performance of safety programme. It is concerned with efficient and effective utilisation of budgeted resources to run a safety programme.

The Efficiency Index can be defined as:

$$\frac{\text{Achievement Index in period z}}{\text{Resource Index in period z}}$$

This model is one of the ways to estimate the amount of money gained/lost in operating a safety programme, how effectively the resources budgeted

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have been used to achieve the targeted safety level and to budget for the future. It also gives a scientific background upon which decision could be made. For this study the following were identified: (1) type of input resource (personnel, information, equipment etc), (2) total number of input resources, (3) the total number of prevented accident by class, (4) the unit cost of each of the accidents class, (5) the cost of input resources and (6) quantity of each type of input resources. It is also important to select a targeted period which is the standard period. The output of a safety programme in a manufacturing company is viewed from reduction in the following: number of accidents that occurred, accident frequency rate, man-hour lost, severity rate etc. If a safety programme is effective and efficient, there will be a reduction in the number of accidents obtained within the observed period. The quantity of the output which is the number of prevented accidents of particular class *i* observed in the period *x* will be high, while its associated monetary value can also determined.

Problem Description and Methodology

Safety is actions, or steps timely taken to avoid occurrence of harmful effect to human or equipment (Adebiyi et al, 2005). To this end, any industrial establishment who ignores or pays little attention to safety can easily go out of business, or better still lose significant trade. All accidents cause losses to the employer, employee, customers, the company and the society. Losses caused by industrial accidents are of two types: material and personnel losses. Though various estimates have been made for the cost of industrial accidents in strictly monetary terms, but there are still some hidden accident costs (Charles-Owaba. and Adebiyi, 2001).

The problem of appropriately quantifying human life is the major problem of costing accident and as such no yet generally accepted model for this. Thus, it depends on the country and circumstances. There is need to provide useful mathematical tool to assist in taking judicious decisions. This study investigates the performance of safety programme of a brewery firm from 2000-2007. Specifically, the number of prevented accidents, the corresponding lives and property saved and the way resources were used to achieve the safety were investigated.

The expected number of accident class i is estimated from safety records before the use of the safety programme using mathematical expectation. Thus the expected number of accident is given by:

$$E(y_i) = y_{i1}\theta(y_i = y_{i1}) + \cdots + y_{ix}\theta(y_i = y_{ix}) \quad 1$$

$$E(y_i) = \sum_{x=1}^{\infty} y_{ix}\theta(y_{ix}) \quad 2$$

Where,

$E(y_i)$: Expected number of accident class i before advent of safety programme.

$\theta(y_i = y_{ix})$: Probability of y_i occurring in period x.

y_i = Number of accidents class i in period x recorded in the period observed.

$$\theta(y_i = y_{ix}) = \frac{f_i}{n} \quad 3$$

f_i : frequency of accident class i that occurred in period before safety programme.

n : total sum of accident class i frequency that occurred over the period observed before safety programme.

In examining the performance of the safety programme, let $z \neq x$ be a safety programme period of the same duration as x and y_{iz} be the observed number of accidents.

If there were no safety programme, then the expected number of accidents is $E(y_{ix})$. But with the safety programme, y_{iz} was observed.

The number of accidents prevented by the programme (A_{iz}), is estimated with this expression:

$$A_{iz} = E(y_i) - y_{iz} \quad 4$$

With a_{i1} as the unit cost of accident class i, then the value of prevented accidents is given by:

$$v_{iz} = a_{i1}[y_{ix}\theta(y_{ix}) - y_{iz}] \quad 5$$

For a firm, the unit cost of accident type a_{i1}, can be estimated from the following components: cost of man-hour lost, legal fee, manpower replacement cost, medical bills, equipment / material replacement cost, compensation paid etc.

However, Ige (1999) identified three classes of accidents in manufacturing industries and estimated the cost of each class of accident as: fatal ₦ 752,000, major ₦ 376,350, minor ₦ 54,000 and wound ₦ 13,500: these shall be used in this study.

The resources input used are: Man-hours spent, Information disseminated, Equipment-hours used and other items used

The resources input index in period z; which is also the measure of how well budget was maintained independent of achievement is given by

$$\varphi_z = \frac{I_z}{I_1} = \frac{\sum_{K=1}^{M} b_{k1} I_{kz}}{\sum_{k=1}^{M} b_{k1} I_{k1}} \quad 6$$

Where: b_{k1} = the unit value or cost of resource k

I_{kz} = the amount of resource k expended during safety programme in period z

I_{k1} = the amount targeted or budgeted.

M = the total number of input k

φ_z = Resource index in period *z*.
The achievement index of this programme for period z, is

$$Q_z = \sum_{i=1}^{N} a_{i1}\left[y_{ix}\theta(y_{ix}) - y_{iz}\right] \qquad 7$$

For planning and controlling safety programme operations using basic principles, a target value of present accidents is stated as follows:

$$Q_1 = \sum_{i=1}^{N} a_{i1}\left[y_{ix}\theta(y_{ix}) - y_{i1}\right] \qquad 8$$

With Equation 8 as targeted and Equation 7 as the actual safety programme achievement, we then have:

$$\psi_z = \frac{Q_z}{Q_1} = \frac{\sum_{i=1}^{N} a_{i1}\left[y_{ix}\theta(y_{ix}) - y_{iz}\right]}{\sum_{i=1}^{N} a_{i1}\left[y_{ix}\theta(y_{ix}) - y_{i1}\right]} \qquad 9$$

Where: Ψ_z = Achievement index in period *z*.
Generally, an industrial system may be simple or complex; this depends on the number of inputs and outputs within such a system. In this study, there are more than one input and output and thus, a complex industrial system.

Efficiency index is obtained by dividing Equation 9 by Equation 6

$$\gamma_z = \frac{\psi_z}{\varphi_z} \qquad 10$$

This implies that

$$\gamma_z = \frac{\left\{\dfrac{\sum_{i=1}^{N} a_{i1}[y_{ix}\theta(y_{ix}) - y_{iz}]}{\sum_{i=1}^{N} a_{i1}[y_{ix}\theta(y_{ix}) - y_{i1}]}\right\}}{\left\{\dfrac{\sum_{k=1}^{M} b_{k1} I_{kz}}{\sum_{k=1}^{M} b_{k1} I_{k1}}\right\}} \qquad 11$$

Where: γ_z = Efficiency index in period *z*.
Ψ_z = Achievement index in period *z*.
φ_z = Resource index in period *z*.
The efficiency index relative to each of the input resource k, γ_{kz}

$$\gamma_{kz} = \frac{\psi_z}{I_{kz} \big/ I_{k1}} \qquad 12$$

According to Charles-Owaba et al (2001), the equivalent naira gained/lost can be formulated for all the resources thus:

$$\Phi_z = (\gamma_z - 1)\sum_{k=1}^{M} b_{k1} I_{kz} \qquad 13$$

And for each Φ input resource k in period z as:

$$\Phi_{kz} = (\gamma_{kz}\text{-}1)\ b_{k\,1} I_{kz} \qquad 14$$

The efficiency index and monetary value can be interpreted as thus:

$$\gamma_z \begin{cases} < 1.0: \text{poor use of all input resources of safety programme.} \\ = 1.0: \text{normal use of all input resources of safety programme} \\ > 1.0: \text{good use of all input resources of safety programme.} \end{cases} \qquad 15$$

and

$$\gamma_{kz} \begin{cases} < 1.0: \text{poor use of input resource k} \\ = 1.0: \text{normal use of input resource k} \\ > 1.0: \text{good use of input resource k} \end{cases} \qquad 16$$

For the monetary value we have,

$$\Phi_z \begin{cases} \text{-ve: money lost for poor use of resources.} \\ 0: \text{money used as planned} \\ \text{+ve: extra savings due to better use of resources.} \end{cases} \qquad 17$$

and

$$\Phi_{kz} \begin{cases} \text{-ve: money lost for poor use of resource k} \\ 0: \text{money used as planned} \\ \text{+ve: extra savings due to better use of resource k} \end{cases} \qquad 18$$

In applying the model, data were collected from the brewery industry on the

(i) Quantities of input for both before and during safety programme.
(ii) Classes of accident.
(iii) Industrial accident data for both before and during programme operations.
(iv) The unit cost of input resources.

The output data before the safety programme were analysed to determine the expected number of accidents in each class, using equation 2. These are found to be **2.0**, **3.0**, **4.3** and **34.9** for **fatal**, **major**, **minor** and **trivial wounds** respectively.

The outputs computation of the safety programme, which includes the number of accidents prevented, was done, using equation 4, and is presented in Table 3. While equation 5 was used in conjunction with Ige's cost estimation earlier stated to obtain the

monetary value of the accidents prevented and the results are presented in Table 4.

For this study Year 2006 was chosen as The Standard Period or Targeted Period. Equation 6 was used to determine the Resources (Effort) Index during the safety programme operation. Equation 9 was used to determine the Achievement Index of the programme, while equation 11 was used to determine the Overall Efficiency Index of the safety programme. Equation 13 was used to determine its equivalent Money Gained or Lost and results are presented in Table 4.

Table 1 Pre-Safety Programme Accidents Records (1984-1991)

Year	Fatal	Major	Minor	Wound	Total
1984	2	2	5	41	48
1985	0	0	4	32	36
1986	1	2	2	30	35
1987	0	0	5	35	38
1988	2	4	6	38	50
1989	0	1	3	28	32
1990	0	3	5	40	48
1991	1	6	4	35	46

The efficiency index due to each of the input resources were determined using equation 12 and equation 14 for its corresponding money gained or lost and results are presented in Table 5.

Table 2 Safety Programme Accidents Records (2000-2007)

Year	Fatal	Major	Minor	Wound	Total
2000	0	0	1	24	25
2001	0	1	0	21	22
2002	1	2	3	29	35
2003	0	0	1	24	25
2004	1	0	0	27	28
2005	0	0	2	19	21
2006	0	1	3	16	20
2007	0	1	3	18	22

Table 3 Summary of Accidents Prevented during the Safety Programme

Year	Fatal	Major	Minor	Wound	Total
2000	2	3	3.3	10.9	19.2
2001	2	2	4.3	13.9	22.2
2002	1	1	1.3	5.9	9.2
2003	2	3	3.3	10.9	19.2
2004	1	3	4.3	7.9	16.2
2005	2	3	2.3	15.9	23.2
2006	2	2	1.3	18.9	24.2
2007	2	2	1.3	16.9	22.2

Table 4 Summary of the Safety Programme Performance

Year	Estimated Number of Prevented Accidents					Values of Lives and Property Saved (Naira)	Efficiency Index	Money Gained/Lost (Naira)
	Fatal	Minor	Major	Wound	Total			
2000	2	3	3.3	10.9	19.2	2,958,400:00	1.291	470,215:31
2001	2	2	4.3	13.9	22.2	2,676,550:00	1.157	255,968:76
2002	1	1	1.3	5.9	9.2	1,278,200:00	0.530	-798,729:80
2003	2	3	3.3	10.9	19.2	2,958,400:00	1.220	376,108:04
2004	1	3	4.3	7.9	16.2	2,219,900:00	1.059	87,163:24
2005	2	3	2.3	15.9	13.2	2,971,900:00	1.156	282,709:35
2006	2	2	1.3	18.9	24.2	2,582,050:00	1.000	-
2007	2	2	1.3	16.9	22.2	2,555,050:00	1.007	12,527:57

Table 5 Summary of the Resources Safety Programme Performance

Year	Human Resourc Used		InformationDisseminated		Equipment Used		Other Resouces Used	
	Eff. Index	Money G/L	Eff. Index	Money G/L	Eff. Index	Money G/L	Eff Ind.	Money G/L
2000	1.48	71,602:29	0.71	-57,734:98	1.37	454,237:25	1.01	855:00
2001	1.24	39,273:28	0.74	-44,698:50	1.21	265,798:13	0.92	-3,510:00
2002	0.59	-63,977:44	0.56	-47,998:07	0.52	-661,470:26	0.44	-25,200:00
2003	1.37	60,018:44	1.30	33,458:04	1.20	280,915:99	1.01	855:00
2004	1.03	5,542:60	1.15	14,554:49	1.06	78,003:16	0.76	-10,620:00
2005	1.20	37,335:83	0.78	-39,581:01	1.19	278,727:63	1.15	6,040:00
2006	1.00	-	1.00	-	1.00	-	1.00	-
2007	0.97	-4,244:77	1.23	23,255:73	0.99	-7,286:63	0.99	-400:00

RESULTS AND DISCUSSIONS

The expected number of accidents in each class is: 2.0, 3.0, 4.3 and 34.9 for Fatal, Major, Minor and Wounds respectively. The computation of efficiency indices due to use of all the input resources show that all the resources are well utilised when compared with the Standard Period whose efficiency index is 1.000, except for year 2002, whose index was below 1.000. From Figure 4.3, the highest efficiency was attained in year 2000. Table 1 shows that year 2006 has the highest number of accident prevented. From Table 4, it is shown that the amount of money spent on the programme (₦ 1,819,835:05) is less than the output of the safety programme (₦ 2,582,050:00) for the Standard Period. Also the highest money saved was recorded in 2005 (₦ 2,971,900:00), while the

least money saved was recorded in 2002 (₦ 1,278,200:00).

The overall efficiency indices for the 8-year period (2000-2007) showed that the safety programme was effective, even though, the total annual efficiency index was not always increasing and it is particularly low in 2002 (0.530). For each of the input resources employed in operating the safety programme, varying amount of money is saved for each year, and the highest money saved is obtained from the use of equipment (₦ 688,924:72) within the period of operating the safety programme, while the highest money lost is from information (₦ 83,121:30).

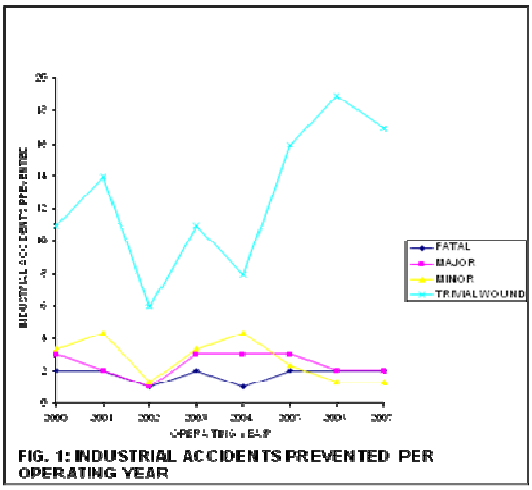

FIG. 1: INDUSTRIAL ACCIDENTS PREVENTED PER OPERATING YEAR

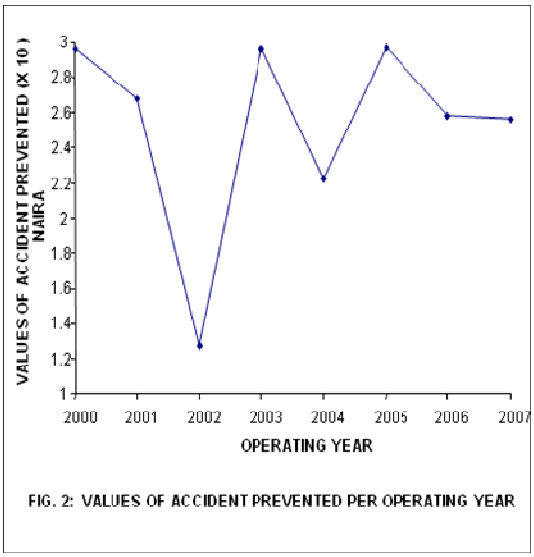

FIG. 2: VALUES OF ACCIDENT PREVENTED PER OPERATING YEAR

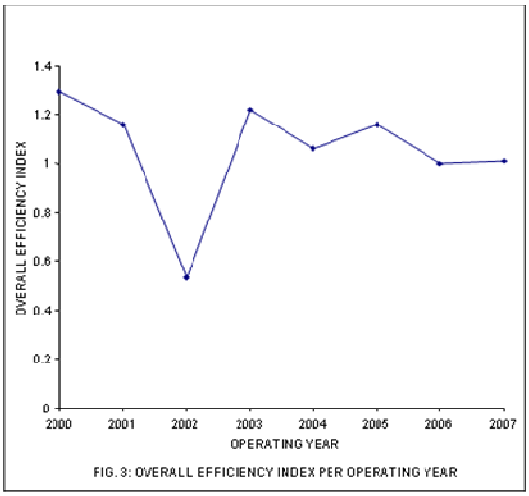

FIG. 3: OVERALL EFFICIENCY INDEX PER OPERATING YEAR

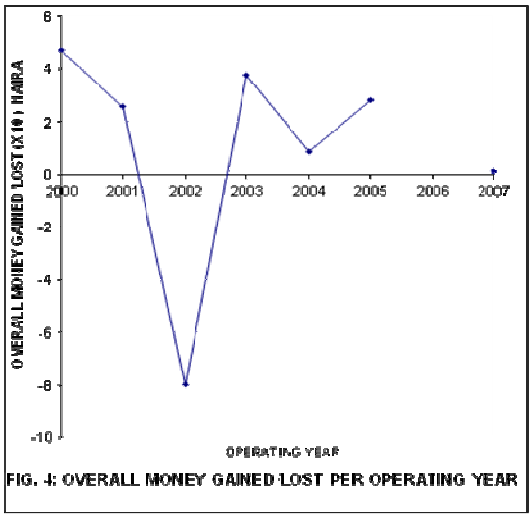

FIG. 4: OVERALL MONEY GAINED LOST PER OPERATING YEAR

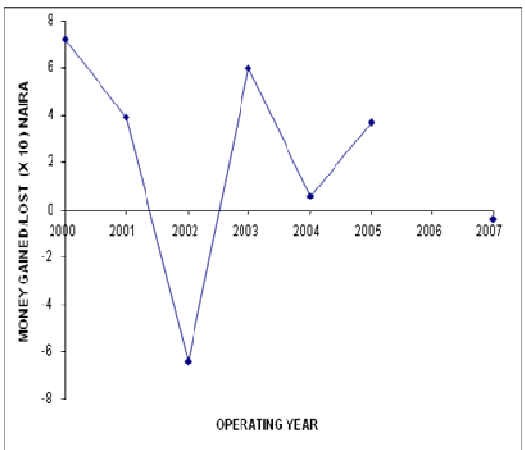

FIG. 5: MONEY GAINED LOST PER OPERATING YEAR FOR HUMAN RESOURCES USED

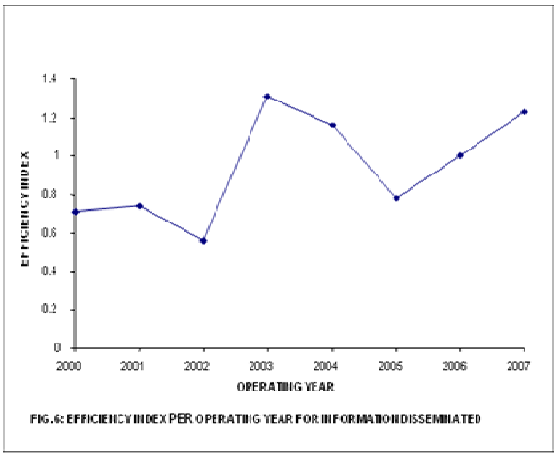

FIG. 6: EFFICIENCY INDEX PER OPERATING YEAR FOR INFORMATION DISSEMINATED

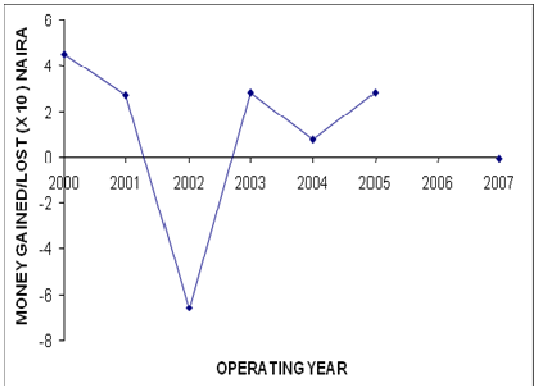

FIG. 9: MONEY GAINED/LOST PER OPERATING YEAR FOR EQUIPMENT USED

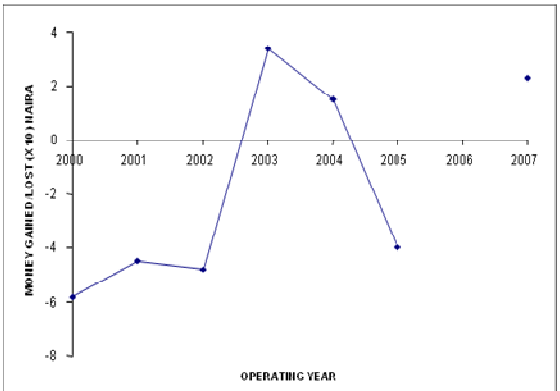

FIG. 7: MONEY GAINED/LOST PER OPERATING YEAR FOR INFORMATION DISSEMINATED

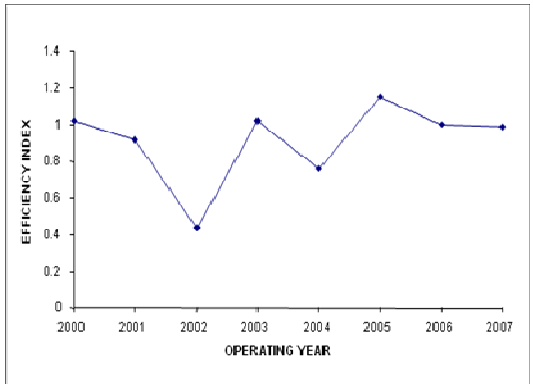

FIG. 10: EFFICIENCY INDEX PER OPERATING YEAR FOR OTHER RESOURCES USED

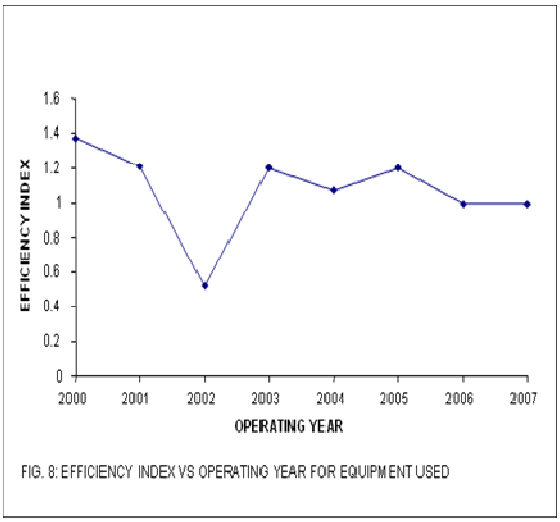

FIG. 8: EFFICIENCY INDEX VS OPERATING YEAR FOR EQUIPMENT USED

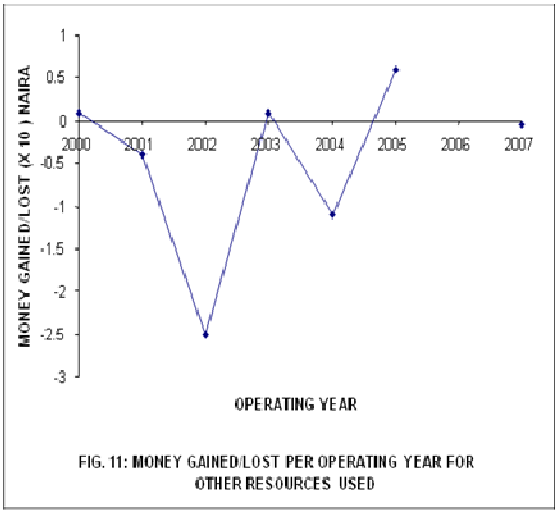

FIG. 11: MONEY GAINED/LOST PER OPERATING YEAR FOR OTHER RESOURCES USED

The safety programme as indicated in Table 4 shows that a total of 24.2 accidents were prevented in the Best Period (Standard Period) of the programme (2006), and the highest money saved due to the overall use of all resources (inputs) is ₦ 470,215:31

in year 2000 and the highest money saved due to the use of single input resource is ₦ 454,237:25 in year 2000 for equipment. The total value of accidents prevented for the safety programme period under consideration (2000-2007) is ₦ 20,200,450:00 and the total amount of money gained due to the use of the safety programme is ₦ 6,646,173:98 (nearly half of the money invested in the programme). The total number of accidents prevented for the same period, under consideration, is 155.6 which translate to an average of 19.45 per year. The implications of the results of the model are that, the model is sensitive to quantity of resources and how the resources are utilised.

Conclusion: This study used the principles of statistical expectation and efficiency index to analyse the performance of safety programme in a brewery industry based in Ibadan, Oyo State of Nigeria. The number of prevented accidents and the corresponding values of lives and properties saved were estimated and results obtained indicate that the programme is efficient, though there is still a need for more improvement, particularly in the use of resources. The firm, through its workers can improve on the performance of the safety programme, by effectively utilizing the input resources provided for them, so as to increase the efficiency of the model. This model is recommended for use for other manufacturing firms, so as to help in setting feasible benchmark for such manufacturing industries.

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