ANALYSIS OF MAINTENANCE IN BREWING INDUSTRIES USING EQUIPMENT UNIFORM ANNUAL COST (EUAC) METHOD

C. O. Nwajinka[1] and B. Udoye[2]
[1]Department of Agricultural & Bioresource Engineering, Nnamdi Azikiwe University, Awka, Nigeria.
[2]Department of Mechanical Engineering, Federal Polytechnic, Oko, Anambra State, Nigeria.
Email: obinwajinka@yahoo.com

ABSTRACT

A study of replacement and maintenance related problems of brewery industries was carried out with view of appraising the maintenance policy of the industry in Nigerian situation. Equivalent Uniform Annual Cost (EUAC) method was used in performing the analysis using data collected from PAL breweries LTD, which they kept for a period of ten years (from 1990 to 1999). Three machines were selected for this study based on their perceived importance in the brewery industry. They are: ammonia compressor, washing machine and filling machine.

The results show that ammonia compressor and filling machine should be replaced or overhauled in their seventh and sixth years respectively. However, this was not done as revealed by the study. The washing machine however did not show visible sign of economic deterioration and should be retained with routine maintenance for the period of study. There was inadequate personnel's training for manpower development, which could be responsible for accelerated machine deterioration. These technical lapses should be addressed by the management of the industry for optimal performance of the industrial machines.

KEYWORDS: Maintenance, replacement, brewery industry, equipment cost.

1. INTRODUCTION

Maintenance can be defined as all activities aimed at keeping the available permanent means of production in a condition or bringing them back into a condition that is considered necessary for a proper fulfillment of their function. This definition implies that a well worked out maintenance schedule contributes greatly to the realization of the company's objectives (Nwajinka, 2005). Therefore a good maintenance and replacement model should be able to predict optimal maintenance and replacement time that will reduce to the possible minimum, the down-time of the equipment (or maximize the undisturbed production time). This undisturbed production time is an inverse function of the time of replacement of the equipment. Replacement and maintenance are not clearly separated. Ackof and Sasien (1984) argued that maintenance is always associated with replacement of components of equipment or the entire equipment, hence all problem situations concerned with controlling the condition of equipment are termed, "problems of maintenance and replacement". Economic replacement theory models attempt to answer the question: "what is the optimum economic life of this piece of equipment? This question suggests that the goal of any replacement is to find an optimum length of time a given piece of equipment is kept in service. After this service life, there is at least one alternative which is more economical than keeping the machine in its present state. This other alternative may be to replace, retire or rebuild (remanufacture) etc.

The objective of this work was to develop a computer program capable of keeping the data base needed for the computation of the Equipment Uniform Annual Costs (EUAC) for major sub-Units of brewing plants as a tool for predicting the replacement and maintenance periods.

2. MATERIALS AND METHODS

2.1 Replacement and Maintenance Models

Decision on equipment maintenance and replacement should be made on sound economic principles and not emotions or mere intuition (Schaevitz, 1988). There are three basic theories in field of economic replacement, which are used in performing the analysis. These are: the cost minimization model, the profit maximization model, and the repair limit model.

2.1.1 Cost Minimization

The theory of cost minimization can be explained quite well graphically. The cost minimization model is depicted graphically in fig 1. Most costs associated with a machine can be placed in one of the two categories: ownership costs and operating costs. The average cost of ownership for a given machine should decrease with its length of service, since most of the capital costs involved with owning a machine are incurred as soon as it is purchased. As time goes on, the initial purchase price is spread over a longer time span and thus the average cost decreases. On the contrary, the average cost of operating a given machine should increase the longer it is kept in service. This is because as a machine is operated, repairs become more frequent and probably more costly. Cost minimization, therefore strives to find a balance point between decreasing ownership costs and increasing operating costs. Three curves depict these phenomena: average ownership costs, average operating cost and average total cost. These cost components are expressed mathematically as follows:

$$Average\ ownership\ cost = \frac{P_o - S_t}{L_t} \qquad (1)$$

$$Average\ Operating\ Cost = \frac{\sum_0^t E_p}{L_t} \qquad (2)$$

$$Average\ Cost\ Per\ Period\ at\ Age\ L_t = \frac{P_o + \sum_0^t E_p - S_t}{L_t} \qquad (3)$$

Where, P_o =initial purchase price
E_p =expenditure for period
S_t =salvage value at time, t
L_t =machine age at time, t.

Average costs are calculated by taking the cumulative costs incurred up to a given point in time and dividing these costs by machine age. Average cost curves are developed for ownership costs and for operating costs. The sum of these two curves (the average total costs curve), slope downwards initially when operating costs are low and the average cost of capital is decreasing. The minimum value of average total cost I^*, the point where the slope of the curve is zero. The optimum economic life L^*, is the period which ends when the sum of owning and operating costs reaches a minimum.

2.1.2 Profit Maximization Basic Model

This alternative method of solving replacement problems was developed in 1925 by Hotelling (Rickards, 1980). Just as in the cost minimization model, profit maximization model can be depicted in a graph. Three lines are depicted on the chat to represent the average total cost, the revenue and the average profit. The average revenue is the average amount of income generated by the asset, while the average profit is determined by subtracting the average costs from average revenue. The optimum economic life occurs at the apex of the average profit curve. If average revenue were constant, the average profit curve would be an exact mirror image of the average cost curve, and the profit maximization economic life would be the same as the cost minimization economic life. However, the amount of revenue generated by an asset often declines with use as the machine suffers from both determination and obsolescence as it ages. As a result of this, the economic lives for profit maximization and cost minimization are not always the same (1975). The cost models for profit maximization are mathematically expressed as follows:

$$Average\ Revenue = \frac{\sum_0^t R_p}{L_t} \qquad (4)$$

2.1.3 The Repair Limit Theory

A third method of tackling replacement problem is the repair Limit theory presented by Drinkwater and Hasting (1967). This method is still in use for replacement decisions. This was defined as a limit on the amount of money which can be spent on the repair of a machine at any particular job. The values of the repair limit are dependent on the type, age, and in some cases on the location of the machine. One of the limitations of repair limit theory is that it is not applied until a machine has broken down. The concept is that there exists some amount, rot below which it is economically sound to repair the machine. If the estimated cost of the repair is greater than rot, the repair should not be undertaken and the machine should be discarded or replaced. A popular expression for estimating the future cost per year if the machine is repaired:

$$\boldsymbol{F_c = \frac{r + m(t)}{g(t)}} \qquad (5)$$

Where, r=the cost of the repair in question; m(t)= the expected total cost of future repairs from time, t, forward; g (t)= the expected remaining life of machine from time, t; t= the time in the machine's life at which point the repair limit evaluation is taken place.

If a field machine is scrapped, then the future cost per year is θ, which is found by determining the average future annual cost of the replacement system. The replacement system is either a new copy of the defender or a challenger that is different. The result of equation (5) is compared to θ. If;

$$\frac{r + m(t)}{g(t)} < \theta \qquad (6)$$

The machine should be repaired and returned to service as soon as possible. If the inequality is not true, then the machine should be scraped and replaced. The repair limit is the value of r for which both sides of the inequality would be equal. Solving for r, the repair limit ecomes;

$$r_0(t) = \big(\theta . g(t)\big) - m(t) \qquad (7)$$

The line OAD is cumulative repair cost against age of machine. The value OA is the original capital cost. The curve AQPD represents the cumulative repair cost over time. The slope θ, represents the average cost of similar machine against which the machine of interest is to be judged. The straight sloping line is tangential to the cumulative cost curve at the point P. the average cumulative repair cost at any point on the cumulative be cost curve is given by the slope of the line drawn from that point to origin of the plot. At a point in the machine's life L_t, the line OW represents the repair limit. Beyond age L_{tp} the repair limit is zero.

The major limits of this model include: (i). It is limited to one type of decision, (ii). The theory cannot be applied until the machine breaks down.

2.2 The Case Study

The case study, PAL Breweries LTD Oko, was established in 1985 under the factories ordinance of 1955 of Federal Republic of Nigeria. The chief products of the company on stream were PAL lager beer and Royal malt. In 1989 the breweries suffered a setback when it had its lager beer product riddled with the problem of gushing. This technical problem caused a hiccup that almost crippled the industry. It however got over this setback and introduced the malt line of production which sustained industry though the lager beer line remained out of circulation. The single line plant was designed to produce 250, 000 hectoliters of the products per annum.

2.3 Machines Studied

To gather data for this study, three machines were selected because of their important positions in the production line (Udoye, 2005). Their importance is underscored by the reason that the breakdown of each of the machines held down production operations with the attendant losses to the company both in time and money. The machines are; Ammonia Compressor, Washing machine (washer), and filling machine (filler). Their purchase and installation prices, year of purchase/installation and their salvage values were extracted from the fixed asset card of the company.

2.3.1 Ammonia Compressor

The Huppman Refrigeration Compressor was purchased and installed in 1986 at the cost of four hundred and seven thousand eight-five kobo (N 407,083.25). its function was provide cold storage for liquid products components. It's perfect operating condition is based on the permissible load, skilled attendance and regular maintenance.

2.3.2 Washing Machine

The contitakt single-end brand of washing machine was purchased in 1986 at the cost of seven hundred and thirty-two thousand, seven hundred and forty-nine Naira eighty-five kobo (N732, 749.85). The function was to provide clean bottles for filling the products. The prescribed operating condition was highly dependent on the preventive/plan maintenance as stipulated in the Huppman Engineering Company, PBL machines manual.

2.3.3 Filling/Crowner Machine

The Ohansa brand filler/crowner was purchased and installed in 1986 at the cost of six hundred and two thousand four hundred and eighty three Naira twenty-one kobo (N602,483.21). the function of this machine was to fill washed bottles with the liquid products while the crowning machine attached to it seals the bottles with crowncorks.

2.4 Equipment Uniform Annual Cost (EUAC)

The EUAC method of replacement analysis was used in this study. The computation involves the annual step calculation of EUAC as shown below:

$$(EUAC)_N = \sum_{i=0}^{N} GN(A/P, i\%, N)$$

$$GN = LN(P/F, i\%, N)$$

$$LN = DN + RN + iSN$$

$$\mathrm{P/F} = \frac{1}{(1+\mathrm{i})^{\mathrm{N}}}$$

$$A/P = \frac{i(1+\mathrm{i})^{\mathrm{N}}}{(1+\mathrm{i})^{\mathrm{N}} - 1}$$

Where, DN=Depreciation for, 1…N years; RN= Operating cost for, 1…N years; SN= Salvage value for, 1…N years; *i*SN= Cost of capital at I interest rate; N=Infinite number of years; P/F=Present worth factor; A/P=Capital recovery factor

2.5 Computation of EUAC

A program was written in Dbase III+ to assist in handling the tedious computational effort and large volume of data required in the database management for the machines' EUAC and maintenance records. The main menu provides platform for machine programs, update and editing of record. The sub-programs include the following: add record, edit records, display record, print or generate report, and computation of EUAC. The illustrative systems flow chart is presented in Fig. 1 and 2.

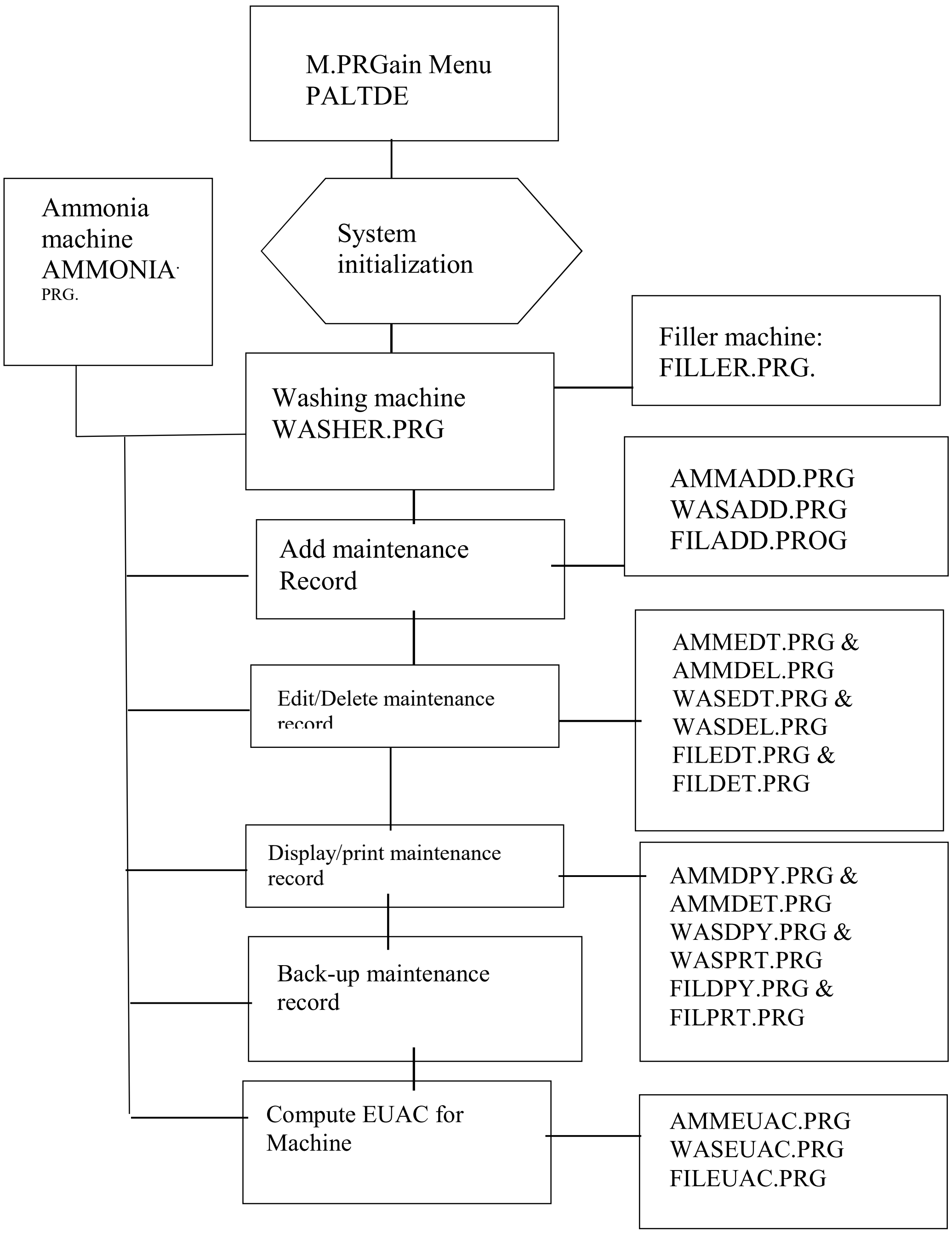

Fig. 1: The system flowchart for computation of EUAC

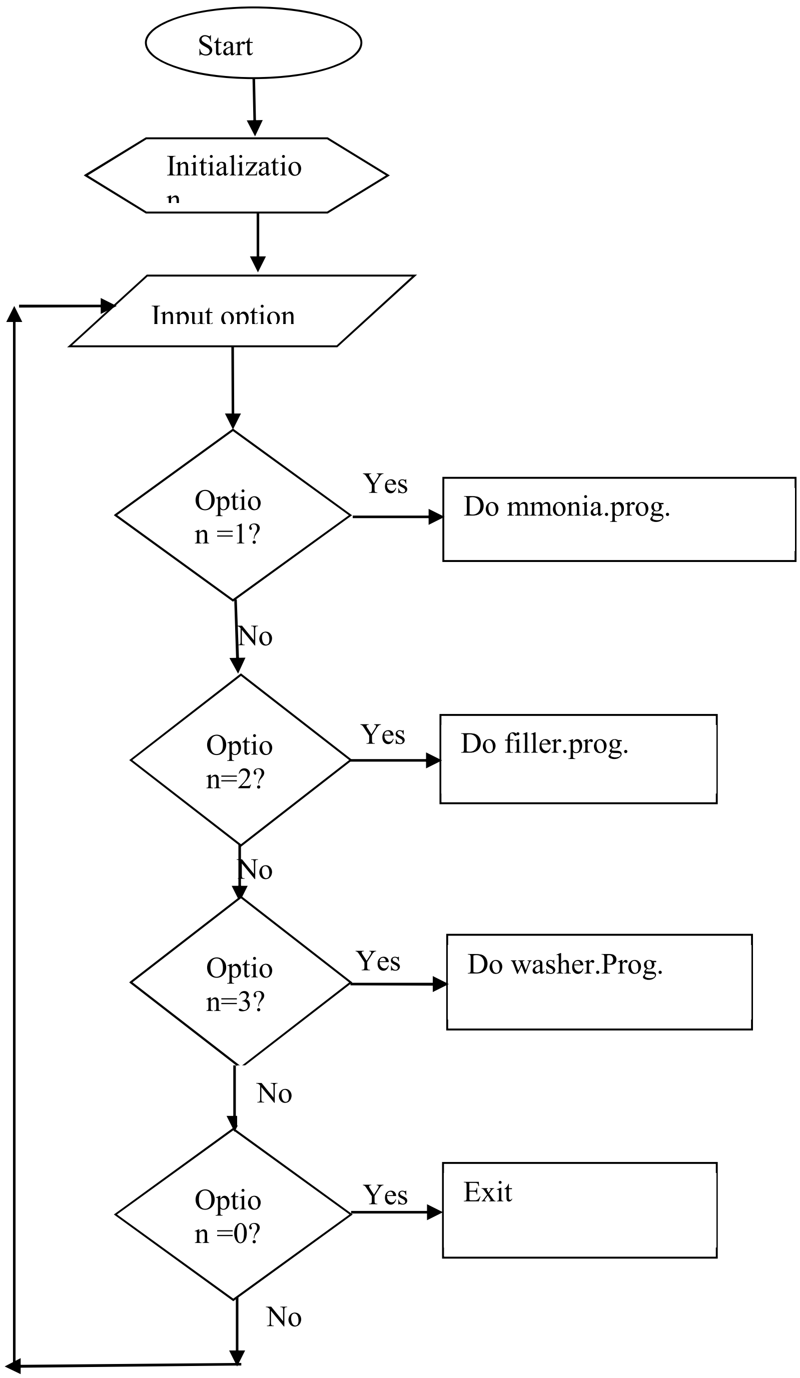

Fig. 2. System flowchart for computation of EUAC

3. RESULTS AND DISCUSSION

The results of the computations are shown in Tables 1 – 3 and Figs 3 – 5.

Table 1: Result of computation of Depreciation of Ammonia Compressor using Declining balance method (interest rate =15% and rate of return=10%)

N (Yrs)	SN(₦)	DN(₦)	RN(₦)	iSN(₦)	LN (DN+RN+ iSN)	GN [LN(P/F, i%,N)]	$\Sigma \; GN(A/P, i\%, N)$
1990	250,0 00.00	-	-	-	-	-	-

1991	212,500.00	37,500.00	21,095.00	25,000.00	83,595.00	75,996.21	83,595.83
1992	180,625.00	31,875.00	10,240.00	21,250.00	63,365.00	52,364.84	73,961.64
1993	153,531.25	27,093.75	10,660.00	18,062.50	55,816.25	41,934.75	68,475.94
1994	130,501.56	23,029.69	2,200.00	15,353.13	40,582.82	27,718.07	62,473.38
1995	110,926.33	19,575.23	0.00	13,050.16	32,625.39	20,257.10	57,579.88
1996	94,287.38	16,638.95	5,740.00	11,092.63	33,471.58	18,894.71	54,453.24
1997	80,144.27	14,143.11	68,400.00	9,428.74	91,971.85	47,199.95	58,408.70
1998	68,122.63	12,021.64	113,250.00	8,014.43	133,286.07	62,177.95	64,942.27
1999	57,904.24	10,218.39	69,500.00	6,812.26	86.530.65	36,723.09	66,535.09

Table 2: Result of computation of Depreciation of Washing machin using Declining balance method (interest rate =15% and rate of return=10%)

N (Yrs)	SN(₦)	DN(₦)	RN(₦)	iSN(₦)	LN (DN+RN+i SN)	GN [LN(P/F, i%,N)]	$\Sigma\, GN(A/P, i\%, N)$
1990	450,000.00	-	-	-	-	-	-
1991	382,500.00	67,500.00	25,784.00	45,000.00	138,284.00	125,713.98	138,285.38
1992	325,125.00	57,375.00	37,573.50	38,250.00	133,198.50	110,075.24	135,861.75
1993	276,356.25	48,768.75	18,992.00	32,512.50	100,273.25	75,335.29	125,103.17
1994	234,902.81	41,453.44	9,694.00	27,635.63	78,783.07	53,808.84	115,136.47
1995	199,667.39	35,235.42	0.00	23,490.28	58,725.70	36,462.79	105,888.30
1996	169,717.28	29,950.11	6,350.00	19,966.74	56,266.85	31,762.64	99,453.26
1997	144,259.69	25,457.59	16,130.00	16,971.73	58,559.32	30,052.64	95,143.63
1998	122,620.74	21,638.95	28,200.00	14,425.97	64,264.92	29,979.59	92,424.00
1999	104,227.63	18,393.11	45,870.00	12,262.07	76,525.18	32,454.33	91,252.03

Table 3: Result of computation of Depreciation of filling machine (filler) using Declining balance method (interest rate =15% and rate of return=10%)

N (Yrs)	SN(₦)	DN(₦)	RN(₦)	iSN(₦)	LN (DN+RN+i SN)	GN [LN(P/F, i%,N)]	$\Sigma\, GN(A/P, i\%, N)$
1990	370,000.00	-	-	-	-	-	-
1991	314,500.00	55,500.00	25,735.00	37,000.00	118,235.00	107,487.44	118,236.18
1992	267,325.00	47,175.00	43,800.00	31,450.00	122,425.00	101,172.02	120,229.58
1993	227,226.25	40,098.75	19,865.00	26,732.50	86,696.25	65,134.89	110,092.71
1994	193,142.32	34,083.94	8,590.00	22,722.63	65,396.57	44,665.86	100,474.20
1995	164,170.97	28,971.35	0.00	19,314.23	48,285.58	29,980.52	91,918.66
1996	139,545.32	24,625.65	74,850.20	16,417.10	115,892.95	65,421.57	95,022.78
1997	118,613.52	20,931.80	121,154.43	13,954.53	156,040.76	80,080.12	101,455.77
1998	100,821.49	17,792.03	65,070.00	11,861.35	94,723.38	44,188.46	110,315.77
1999	85,698.27	15,123.22	52,120.00	10,082.15	77,325.37	32,793.69	107,885.37

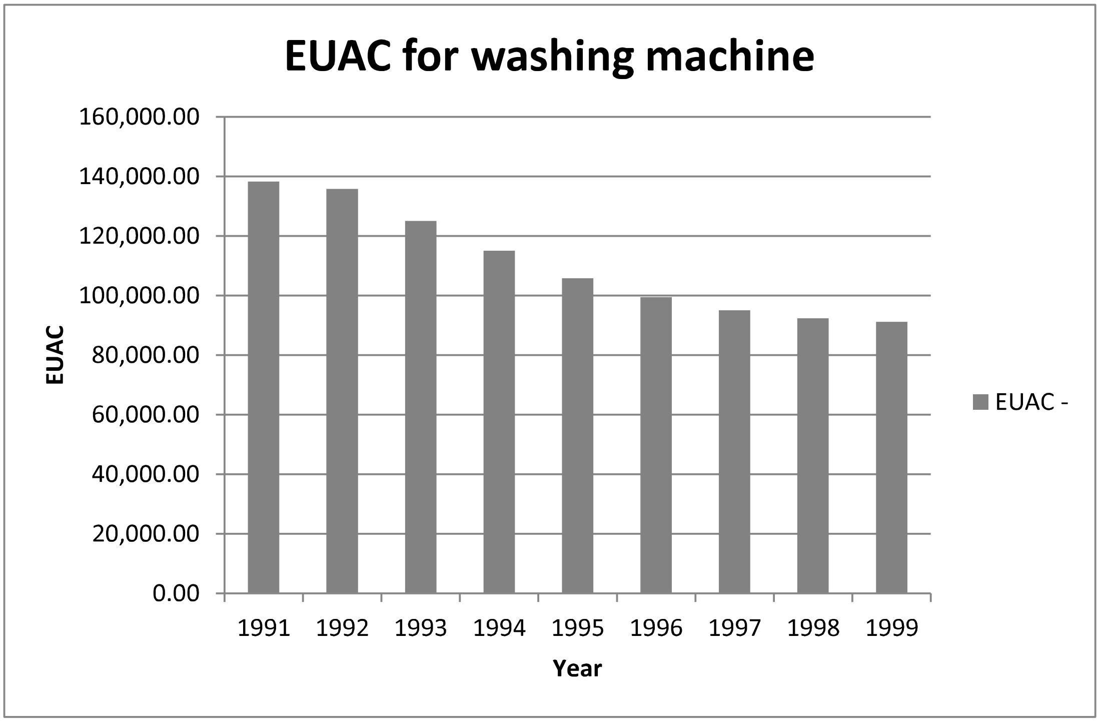

Figure 3: A plot of EUAC against year for washing machine at 10% interest rate and 15% depreciation rate.

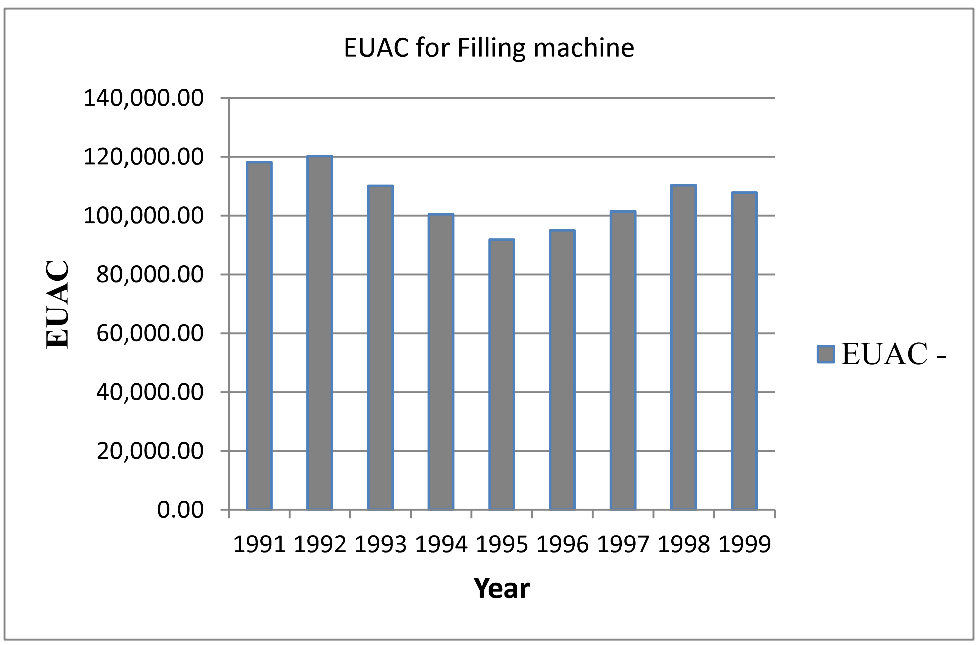

Figure 4: Plot of equivalent Uniform Annual Cost of filling machine against year at 10% interest rate and 15% depreciation rate.

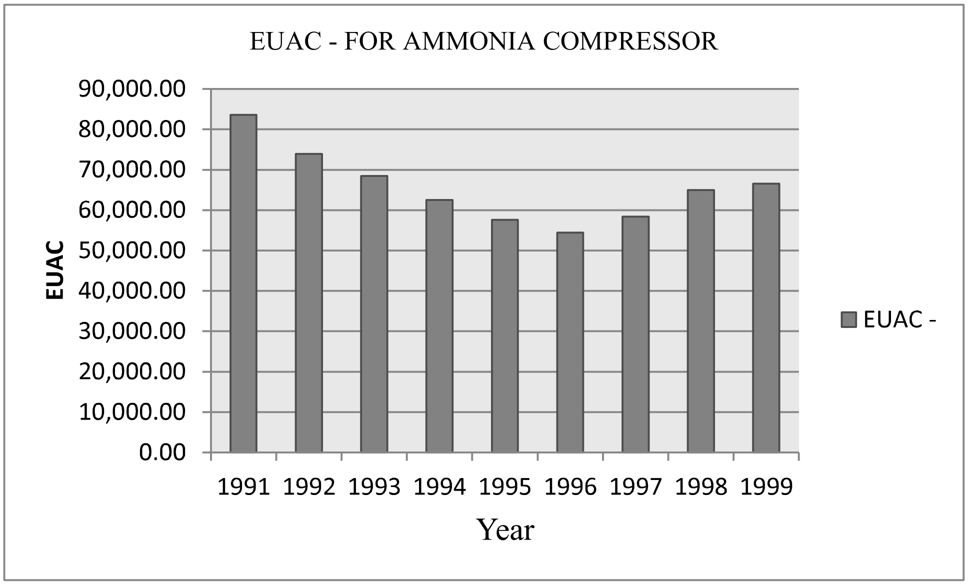

Figure 5: Plot of EUAC against year for Ammonia Compressor at 10% interest rate and 15% depreciation rate.

For a favorable machine condition, the EUAC for a particular year will be less than that of the previous year. When the EUAC of a particular year is greater than that of the previous year, it signifies deterioration of the machine, given that all other conditions for effective running of the machine are in place. At this point, it may be apt to embark on major repair or outright replacement of the equipment. Where this is ignored and the machine continues to run, there is an accumulation of running cost that is usually exorbitant.

For the Ammonia Compressor, the EUAC started to increase from the seventh year (ie. In 1997: see table 6) having reached the minimum value in 1996. This shows that the machine was due for either major maintenance or replacement at that point (1996) for optimal performance and costs minimization.

For the washing machines, the EUAC did not show any minimum value within the years studied. This indicated that the machine had a longer service life than the period of study and should go on with routine maintenance and checks. This is a favorable attribute for the machine.

The EUAC for the filling machine was minimum in the fifth year (1995) and started increasing in 1996. As is the rule it was due for major maintenance or replacement in the year 1996, whichever is more convenient to the company.

It was observed that output result for all the machines' RN was zero in 1995. This was explained by the reason that the company did not engage in production that year due to the technical problem that propped up in the factory which forced it to shut down. It was not possible to extend the study to the year of purchase of the machines studied due to non-availability of the maintenance and replacement records.

Inadequate technical data records which were observed could be traced to unskilled workers which dominated the industry. Interaction with staff of the company revealed that junior staff made up about 70% of roughly 250 staff engaged by the company. There was no training scheme for the technical personnel and machine operators. Inadequate stocking of spare parts and purchase of inferior and used parts prolonged down-time of the broken down machines and resulted in poor maintenance jobs. Above all, there were poor records of inventory and maintenance operations.

4. CONCLUSIONS

The EUAC method of replacement and maintenance analysis used in this study was found to be useful as a veritable tool for techno-economic analysis of machine systems. The record keeping for such analysis is usually very tedious and requires a robust database to keep and make data records available for use in a time-saving and convenient manner. These computer-aided models could run the database as well as compute EUAC needed for decision making in replacement and maintenance situations within a very short time by any person who can drag the mouse of a computer.

The results show that ammonia compressor and filling machine should be replaced or overhauled in their seventh and sixth years respectively. However, this was not done as revealed by the study. The washing machine however did not show visible sign of economic deterioration and should be retained with routine maintenance within this period of study. This could be as a result of underutilization of the machines. Inadequate manpower development could be responsible for accelerated machine deterioration. These technical lapses are recommended for redress by the management of the industry for optimum performance.

REFERENCES

Ackof L.R , Sasien M.W 1994. Foudamentals of operations research, Wiley Eastern LTD, New Delhi.

Kalavathy S. 2000. Operations research. Second Edition. Vikas Publishing house PVT LTD. New Delhi.

Nwajinka C.O. 2005. Design of a Computer Database for Equipment replacement and Maintenance: A Case Study. M.Eng thesis submitted to the department of Mechanical/Production Engineering, Nnamdi Azikiwe University, Awka.(Unpublished).

Rickards, J. 1980. Capital Expenditure and Replacement Strategies in an Inflationary Economy. *LOG National Meeting.* Toronto: CPPA Logging Operations Group - Maintenance and Service Committee.

Schaevitz, R. 1988. Use of life-cycle cost analysis in transit capital overhaul/replace decisions – An application to the path railcar fleet. *Transportation Research Record, 1165*, 11-18.

Udoye B.O 2005. A study of maintenance related problems in PAL Breweries LTD, Oko. An M.Eng thesis submitted to the department of Mechanical/Production Engineering, Nnamdi Azikiwe University, Awka. (Unpublished).