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Application of lean manufacturing technology in a milk manufacturing company

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A B S T R A C T

This work presents the application of lean management principle in the area of waste elimination in a powder milk plant of a production company. The existing manufacturing procedure for the company's plant was evaluated, and a lean manufacturing technique was developed for the plant. To achieve this, a time series analysis was carried out on the econometric data obtained, and a future forecast predicting losses and usage was predicted based on the practised manufacturing procedures. The econometric linear transfer function technique applied to the actual usage and actual loss data obtained filtered the waste in the production process and generated forecast values for actual loss and usage. This revealed that there had been poor manufacturing practices in the factory. The findings from this research can be used as a guide to managers on wastage control in a production system.

1. INTRODUCTION

The ever re-occurring global economic crisis usually led to collapse in the production system of industries and they eventually affect the demand for goods and services from consumers [1], [2]. This crisis led to industries struggling for survival by cutting down on expenses that affected quality (in some cases) and some shutting down facilities while others merged. However, Anthony [3] argued that period as such should be an opportunity for industries to reengineer and tailor operation towards lean production to reduce waste and avoidable expenses across the production stages while quality is enforced all through the production stages.

Also, Most companies nowadays, due to many competitors in the market, are forced to adopt tools and techniques in production of goods to promote cost reduction with quality being maintained to remain sustainable and meet raising demands [4]. Lean management principles and techniques ensure an efficient production mechanism for any firm to remain sustainable without compromising quality. As introduced in the Toyota production system, the concept of lean manufacturing is to improve quality delivery and production process optimization via the reduction in both waste generation and inventory [5]. According to Dudbridge [6], lean is that meat part that is fat-free (i.e. principally consisting of lean muscle) hence, lean thinking aims at reduction of wastes (fats) that are detrimental and of a burden on any system. Lean as Lean Enterprise, Lean Management or Manufacturing (LM), Lean Production, and defines it as sets of principles, tools and techniques implemented by companies/organizations to heighten their efficiency in production by aiming at waste reduction in adding values to customers [7]. In another perspective lean manufacturing aim at having same output with lesser input; these inputs include less cost, less human effort, less machinery, less material, less space and less time [6]. Lean can be defined as a systematic approach used in waste identification and elimination by combining sets of tools and techniques utilized in continuous improvement on product and service firms rendered. The importance of having a manufacturing system based on lean manufacturing is enormous, including quality improvement in the production system, waste elimination in the production system, and production cost reduction, which directly affects societal prosperity [1], [8].

In as much as lean principle has a positive influence on any company's effectiveness, efficiency that brings about an increase in productivity, value addition and at the same time, reduction in waste, not all of the principles are applicable to all industries; hence, the need to first analyze and measure its essentials [9], [10]. Some organizations/companies have failed to implement lean practices due to a lack of understanding and performance measures, hence, the need for quantitative models [11] to appraise lean performance, its effectiveness on the production system and seek areas for potential improvements decision-makers of the organization.

The concept of lean thinking can be categorized into value identification, waste elimination, and Flow Generation [12]. This concept of lean thinking leads to the five key principles of lean manufacturing as reported by El Faydy & El Abbadi [13], which are the elimination of waste; identification of the value stream; achievement of flow through the process; pacing by a pull signal, and continuous pursuit of perfection.

Of all these five principles, eliminating waste is the focus of this research whose case study is a milk manufacturing company in Nigeria. In industry, waste is referred to as anything that adds no value to the end product of manufactured goods [14]. This industrial waste is of two types: Seen/Calculated Waste and Unseen / Uncalculated Waste. The Seen/Calculated Waste includes breakdown and defects, while Unseen/Uncalculated Waste includes waste due to improper transportation of materials and men and an improper working environment. However, these types of industrial waste are embedded in the three types of waste identified by the lean concept, which are: Mura (Unevenness), Muri (Overburden) and Muda (activities that have no value addition to customers). This type of waste can also be divided into seven types: overproduction, inventory, extra processing steps, motion, defects, waiting, and transportation [15]. In agreement with in order to align with the objectives of the lean practice, the milk production company identifies the need to reduce waste generation to the highest possible level in pursuit of satisfying their customers demand and optimizing the company's losses [16], [17].

The powder factory at the Milk Company understudied is in a batch production establishment. The existing production methods have resulted in certain levels of profits and losses over the period being studied. This research understudied these outputs in relation to the concerned inputs to develop a lean manufacturing practice for this powder factory.

2. RESEARCH METHODS

This research was conducted based on secondary data obtained from the company. A monthly record of actual usage of raw materials, actual loss of raw materials and the associated monetary loss for five (5) years was developed into a time series data of sixty (60) months. The research project employed econometric models in evaluating the data obtained from existing methods of production. This econometric model consists of some input processes, which are autoregressive (AR) and moving average (MA). The hybrid of these two-time series processes formulates the linear transfer function as expressed in equations (1) and (2). The MA process was carried out on the actual usage data (xt), while the AR process was carried out on the actual loss data y_t. The actual loss data had a sinusoidal pattern that encircled the abscissa, while the actual usage data had an increasing pattern.

$$Y_t = V_1(B)X_t + u_{1t} \quad (1)$$

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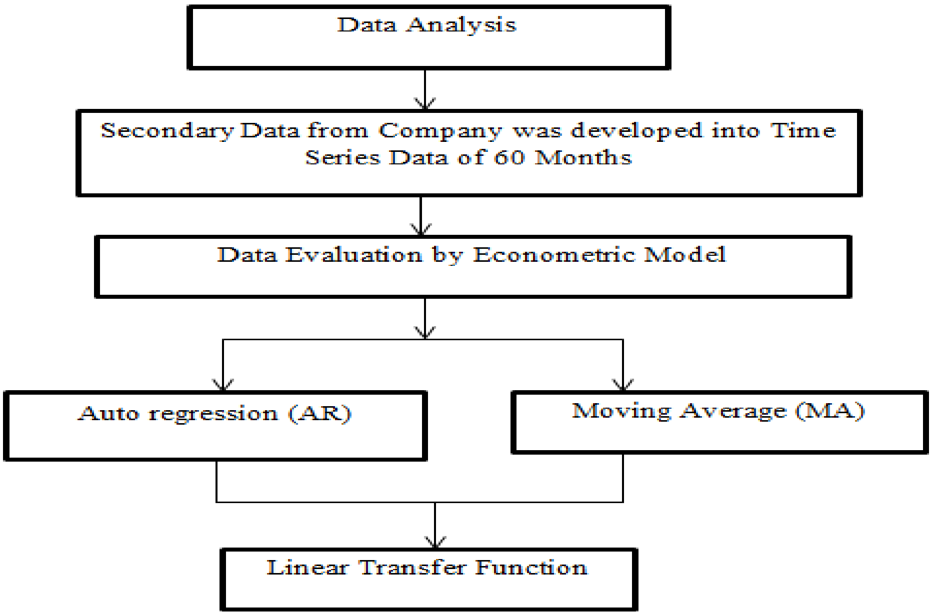

Fig. 1. Flowchart of research methods

$$X_t = V_2(B)Y_t + u_{2t} \quad (2)$$

Where t = 1,2,……,n and

$$V_1(B) = v_1 B + v_2 B^2 + \cdots + v_s B^s \quad (3)$$

$$V_2(B) = \omega_1 B + \omega_2 B^2 + \cdots + \omega_\theta B^\theta \quad (4)$$

The auto-regression analysis was carried out on the actual loss data. The functional analysis for this auto regression modelling was the computation of autocorrelation function (ACF), usually represented as r_k, which was carried out by taking three or four lags on the time series. r_k for each lag was computed based on the formula for r_k given as $r_k = \frac{\sum(y-\bar{y})(y_{t-k}-\bar{y})}{\sum(y_t-\bar{y})^2}$. The best three lags are rated as the best candidate for the autoregression analysis. The second, third and fourth lags were selected and used for the autoregression (AR) analysis.

The moving average analysis was carried out on the actual usage data in which its model was analyzed through the computation of the autocorrelation function (ACF). The ACF computation took three or four lags on the time series and computed the r_k for each lag. The best three lags are rated as the best candidate for the moving average analysis. The formula for r_k is given as $r_k = \frac{\sum(x-\bar{x})(x_{t-k}-\bar{x})}{\sum(x_t-\bar{x})^2}$.

The second, third and fourth lags were selected and used for the moving average (MA) analysis. Also, multivariate analysis was performed on the actual loss, actual usage and the monetary loss, in which the monetary loss was the response variable for the multivariate analysis. The research flow diagrammatic illustration is as shown in Fig. 1.

3. RESULTS AND DISCUSSION

From the results of the research conducted, the following conditions were obtained. The summing variables for the AR process were used to develop a set of normal equations as shown in equations (5) to (8). these normal equations were represented in canonical form as shown in equations (9) to (11).

$$293725 = 60\beta0 + 285465\beta1 + 283195\beta2 + 281807\beta3 \quad (5)$$

$$940535327 = 285465\beta0 + 6360716901\beta1 + 2569017347\beta2 + 925740015\beta3 \quad (6)$$

$$1884227816 = 283195\beta0 + 2569017347\beta1 + 6355564001\beta2 + 2565866587\beta3 \quad (7)$$

$$975933821 = 281807\beta0 + 925740015\beta1 + 2565866587\beta2 + 281807\beta3 \quad (8)$$

$$A = \begin{pmatrix} 293725 \\ 940535327 \\ 1884227816 \\ 975933821 \end{pmatrix} \quad (9)$$

$$B = \begin{pmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \beta_3 \end{pmatrix} \quad (10)$$

$$C = \begin{pmatrix} 60 & 285465 & 283195 & 281807 \\ 285465 & 6360716901 & 2569017347 & 925740015 \\ 283195 & 2569017347 & 6355564001 & 2565866587 \\ 281807 & 925740015 & 2565866587 & 281807 \end{pmatrix} \quad (11)$$

The regression parameters associated with these normal equations were determined by equation 12.

$$B = invC * A \tag{12}$$

Represented in vector form as shown in equation (9) to (11), with $\beta_0 = -1042.46781766808$, $\beta_1 = -0.15377430226$, $\beta_2 = 0.55023095656$, $\beta_3 = 0.86707425476$ Thus, the developed AR model for the actual loss data is shown in equation (13).

$$\tilde{y} = -1042.47 - 0.15377y_{t-2} + 0.55023y_{t-3} + 0.86707y_{t-4} \tag{13}$$

The developed auto regression model is shown in equation (13) was used to predict both in-sample and out-of-sample forecasts. The in-sample predictions using the AR model are shown in Table 1, while the out-of-sample forecast is shown in Table 2.

Table 1. In-sample prediction using the AR model developed

T	Actual (y_t)	Forecast ($\tilde{y}_t$)	Error	e^2
55	3,296	3326.84537	-31	951.4368504369
56	-6,613	3213.29137	-9,826	96,556,002.088137
57	1,388	4717.26865	-3,329	11,084,029.743873
58	2,270	6257.71494	-3,988	15,901,870.442699
59	4,484	-2036.71103	6,521	42,519,672.336764
60	3,776	-6361.74257	10,138	102,773,824.41559

Table 2. Out-of-sample prediction using the AR model.

T	Forecast($\tilde{y}_t$)
61	720.54058
62	2812.3747

The in-sample AR forecast with the least associated error is $\hat{y}_t = 55$. This was used to determine the linear transfer function parameter because it has the lowest in-sample forecast residual. The AR model could predict two-step out-of-sample values. These values were used as input for the econometric LTF future forecast model. The summing variables for the MA process were used to develop a set of normal equations as shown in equations (14) to (17). Likewise, the normal equations were represented in canonical form as shown in equations (18) to (20).

$$146588158 = 60\beta_0 + 140500671\beta_1 + 136623205\beta_2 + 132994737\beta_3 \tag{14}$$

$$37093584655521 = 140500671\beta_0 + 369752991451883\beta_1 + 354586958467409\beta_2 + 348099813194622\beta_3 \tag{15}$$

$$361175824689160 = 136623205\beta_0 + 354586958467409\beta_1 + 354718248870727\beta_2 + 340517697165321\beta_3 \tag{16}$$

$$353738008680098 = 132994737\beta_0 + 348099813194622\beta_1 + 34517697165321\beta_2 + 341552468843703\beta_3 \tag{17}$$

$$A = \begin{pmatrix} 146588158 \\ 370935846555212 \\ 361175824689160 \\ 353738008680098 \end{pmatrix} \tag{18}$$

$$B = \begin{pmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \beta_3 \end{pmatrix} \tag{19}$$

$$C = \begin{pmatrix} 60 & 140500671 & 136623205 & 132994737 \\ 140500671 & 369752991451883 & 354586958467409 & 348099813194622 \\ 136623205 & 354586958467409 & 35471824880727 & 340517697165321 \\ 132994737 & 348099813194622 & 340517697165321 & 341552468843703 \end{pmatrix} \tag{20}$$

The process parameters associated with these normal equations were obtained via equation (12), using MATLAB software and are as follows: $\beta_0 = 823214.886180650$, $\beta_1 = 0.426269183$, $\beta_2 = -0.006499655$, and $\beta_3 = 0.287170479$. Thus the developed MA model for the actual usage data is shown in equation (20). The developed moving average model is shown in equation (21) was used to predict both in-sample and out-of-sample forecasts. The in-sample predictions using the MA model are shown in Table 3, while the out-of-sample forecast is shown in Table 4.

$$\tilde{x} = 823214.886 + 0.426269x_{t-2} - 0.0064997x_{t-3} + 0.28717x_{t-4} \tag{21}$$

Table 3. In-sample prediction using the MA model developed

T	Actual (Xt)	Forecast ($\tilde{x}_t$)	Error	e^2
55	2957342	3465731.63	-508390	58460014025
56	3861317	3299340.96	561976	15817075139
57	3628468	3086957.85	541510	93233247468
58	3877466	3545557.74	331908	10163093118
59	3084324	3194080.82	-109757	12046557764
60	3003163	3561328.89	-558166	31154916051

Table 4. Out-of-sample prediction using the MA model.

T	Forecast ($\tilde{x}_t$)
61	3154751.383
62	3196814.905

The in-sample MA forecast with the least associated error is $\hat{x}_t = 59$. This was used for the determination of the linear transfer function

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parameter because it has the lowest in-sample forecast residual. The MA model could predict two-step out-of-sample values. These values were also used as input for the econometric LTF future forecast model.

3.1. Backshift operator for linear transfer function

The backshift operator for both AR process and MA process was obtained using the following formula: Backshift operator for y (loss) series is

$$B_x = \frac{Y_{i-1}}{Y_i} \tag{22}$$

and that of actual usage (x series) is

$$B_y = \frac{X_{i-1}}{X_i} \tag{23}$$

This form part of the inputs for the classical econometric linear transfer function model for the actual and loss data as shown in equations (24) and (25).

$$y_t = V_1(B_y)x_t \tag{24}$$

$$x_t = V_1(B_x)y_t \tag{25}$$

V1 and V2 are the linear transfer components associated with the various backshift operators. The computations of the components of equations (24 and 25) are carried out using Microsoft Excel software as shown in Appendix 1.

3.2. Determination of linear transfer function components (LTF)

The AR component of the LTF is expressed as follow. AR = $V_1(B_y)x_t$. The forecast value of AR at t=55, $y_{t=55}$=3326.85. The backshift operator at t=55, $B_yx_{t=55}$ =4625333.134. Then $V_1 = \frac{AR_{55}}{B_Y x_t} =$ 0.00071926. For the MA components of the LTF, forecast value at t=59 was used. Where $Xt_{=59}$= 3196814.91 and B_xy_t= 5637.072352,

$$V_2 = \frac{MA_{59}}{B_x Y_t} = 566.62$$

3.3. Classical econometric linear transfer function model evaluation (ELTF)

The developed econometric linear transfer function model is of the form shown in equations (26) and (27).

$$Y_t = 0.00071926 B_y x_t \tag{26}$$

$$X_t = 566.62 B_x y_t \tag{27}$$

Table 5. Out-of-sample computations for the backshift operators

Months	Actual usage	Backshift operator	Loss	Backshift operator		
T	X	Bx	Y	By	Byxt	BxYt
61	3154751.383	0.951949183	720.54058	5.240509841	16532505.67	685.9180161
62	3196814.905	0.986842053	2812.3747	0.25620362	819035.5524	2775.369622

Table 6. Out-of-sample computations for the backshift operators

T (s)	B_yx_t	B_xy_t	V_1	V_2	Y_t	X_t
10	403190.036	1116.34	0.000719267	566.62	2899.93	632540.00
20	4524407.227	227.36	0.000719267	566.62	3254.26	128823.89
30	6358903.248	-2600.56	0.000719267	566.62	4573.75	-1473529.31
40	919.76786	-88466390.61	0.000719267	566.62	-63630.96	521158.87
50	34392289.311	24575.08	0.000719267	566.62	2473.77	13924730.70
60	3566257.063	3878.05	0.000719267	566.62	2565.09	2197378.99

Table 7. In-sample econometric LTF evaluation

T	Actual usage, Y	Actual loss, X	ELTF usage X_t	ELTF loss Y_t
10	2236369	1202	632540.00	2899.93
20	1951443	292	128823.89	3254.26
30	2367885	-2782	-1473529.31	4573.75
40	2960672	862	521158.87	-63630.96
50	3302996	24186	13924730.70	2473.77
60	3003163	3776	2197378.99	2565.09

Where the B_yx_t and B_xy_t are the out-of-sample backshift operators, the out-of-sample forecast values for AR (yt) and MA (x_t) were used to compute the forecast values for B_yx_t and B_xy_t, as shown in Table 5. These out-of-sample AR and MA values were used to run the backshift for two subsequent months subsequent (t=61 and t=62). Therefore, the Econometric Linear Transfer Function (ELTF) in-sample evaluations are as computed in Table 6. Hence, the In-sample econometric LTF evaluation is summarized in Table 7. The out-of-sample evaluation of the econometric data was carried out as shown respectively:

Yt=61 = 0.000719267 x 16532505.67
= 11891.28575574389
Xt=61 = 566.629 x 685.9180161
= 388661.0395447269
Yt=62 = 0.000719267 x 819035.55
= 589.10524294185
Xt=62 = 566.629 x 2775.37
= 1572605.12773

3.4. Multivariate analysis of the econometric data

The multivariate analysis of the econometric data was carried out as shown in the follow equation:

$$120883111 = 60\beta_0 + 293725\beta_1 + 146588158\beta_2 \quad (28)$$

$$3394601963077 = 146588158\beta_0 + 6395081333\beta_1 + 706937346281\beta_2 \quad (29)$$

$$279284067699750 = 146588158\beta_0 + 7069373463381\beta_1 + 388285033993428\beta_2 \quad (30)$$

$$A = \begin{pmatrix} 120883111 \\ 3394601963077 \\ 279284067699750 \end{pmatrix} \quad (31)$$

$$B = \begin{pmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \end{pmatrix} \quad (32)$$

$$C = \begin{pmatrix} 60 & 293725 & 146588158 \\ 293725 & 6395081333 & 706937346381 \\ 146588158 & 706937346381 & 388285033993428 \end{pmatrix} \quad (33)$$

The multivariate model for the econometric data will now be written as follow:

$$\hat{y} = 62494.78 + 564.93X_1 - 0.3324X_2 \quad (34)$$

where $\hat{y}$ =monetary loss, X_1=actual loss and X_2=actual usage.

The adjusted coefficient of determination was determined using equation (35) [18].

$$\overline{R^2} = 1 - \frac{\sum(y_t-\hat{y})^2/(n-k)}{\sum(y_t-\bar{y})^2/n-1} = 0.999996 \quad (35)$$

where k = number of parameters, n = number of dependent variables, $\hat{y}$ is the predicted value, y_t is the actual value and $\bar{y}$ is the average value. The R^2 is very high, suggesting a good fit for the data. This means the estimated regression line fit the data very well. The result compare well with literature values such in some cases [19], [20].

3.5. Results of moving average (MA) computation

The data obtained for the actual record of milk powder factory usage or for a period of sixty (60) months is presented graphically in Fig. 2. The plot shows an upward trend and cyclical pattern which suggested that this actual usage did not follow a predetermined and controlled process. Moving average process was carried out and the results showed that the forecast value at t=59 has the least associated error. The plot of the actual and predicted moving average (MA) is shown in Fig. 3.

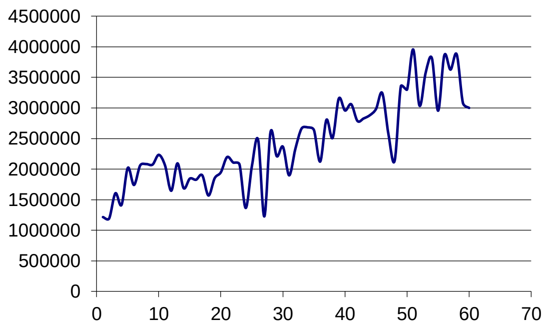

Fig. 2. Plot of actual usage of powder for sixty months

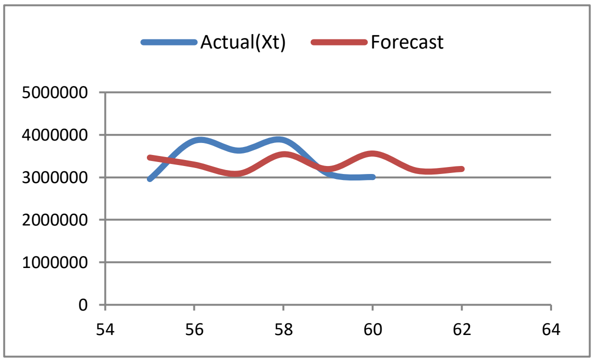

Fig. 3. Plot of actual usage and predicted MA usage

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3.6. Results of autoregression computation

The data obtained for the actual record of milk powder factory losses for a period of sixty (60) months is presented graphically in Fig. 4. The plot shows no upward trend but cyclical pattern which suggested that these actual losses followed a predetermined and controlled process. Also, the auto regression (AR) process was carried out and the results shown in Fig. 5 implies that the forecast value at t=55 has the least associated error.

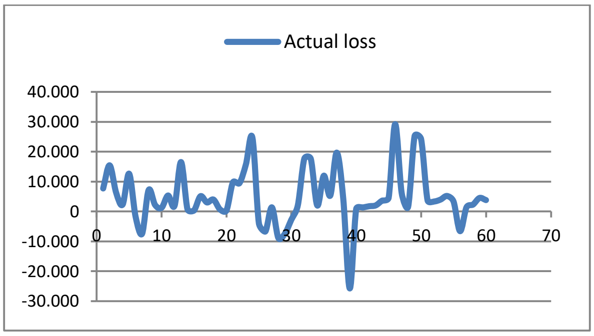

Fig. 4. Plot of actual powder loss for sixty months

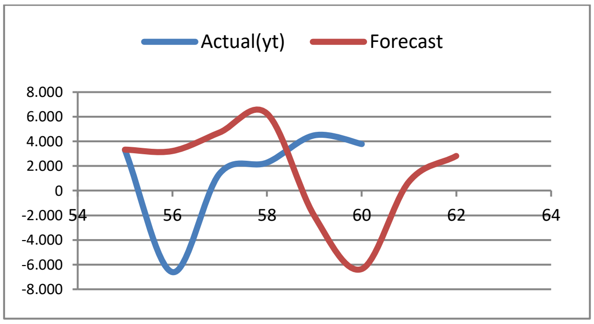

Fig. 5. Plot of actual loss and predicted AR losses

3.7. Results of the econometric forecast

The econometric linear transfer function modelling results revealed that the values for the actual loss declared in the company's records are low compared with the ELTF modelled values. It is evident in Fig. 3 that in the thirtieth month (t=30), the negative loss value was declared, which indicated profit was modelled as a loss value. Also, in the fortieth month (t=40), the actual loss value was modelled as a profit. The graphical representation of the actual losses and the ELTF losses are shown in Fig. 6.

The econometric linear transfer function modelling results revealed that the values for the actual usage declared in the company's records are so low compared with the ELTF modelled values. It is evident that in the thirtieth month (t=30), the negative modelled value obtained against the positive usage value also supported that the negative loss declared for that month was actually supposed to be positive (Fig. 7).

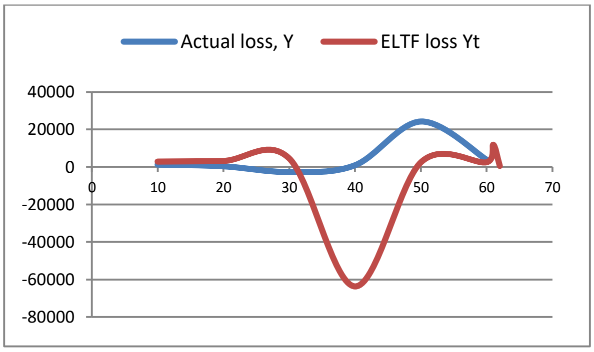

Fig. 6. Plot of actual loss and ELTF loss

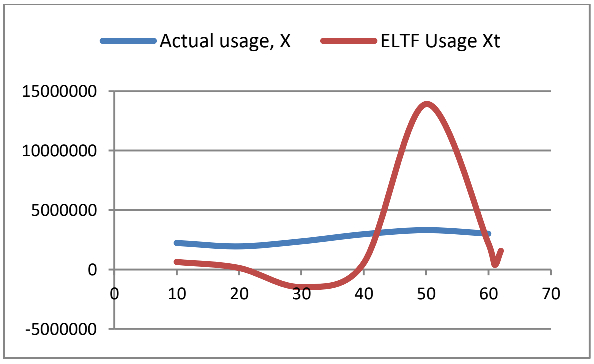

Fig. 7. Plot of actual usage and ELTF usage

The plot of monetary loss/profit is shown in Fig. 8. The plot shows a cyclical pattern which suggests that these actual losses followed a predetermined and controlled process. The multi-variate analysis showed that the monetary loss is dependent on the actual loss and actual usage. A large monetary loss was recorded with a very small value of actual usage.

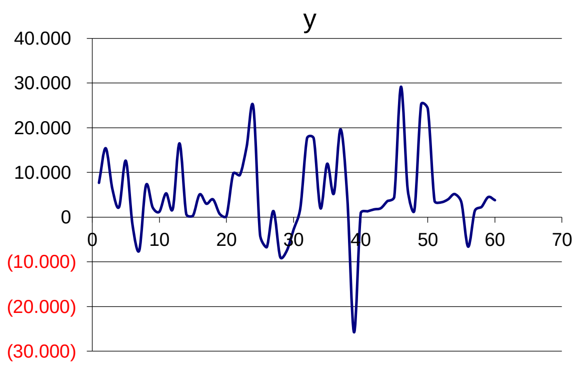

Fig. 8. Plot of monetary loss/profit for sixty months

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4. CONCLUSION

The econometric linear transfer function model developed from the data obtained revealed that the present manufacturing practices at the powder factory had numerous associated losses of materials. The recorded values for actual usage of materials comprised of the waste incurred during the production process. The ELTF model operates a feedback system between the actual usage and actual loss, enabling it to predict the systemized values of losses and materials usage. The ELTF modelled values are based on lean manufacturing principles. This is because the modelled system evaluated the losses and usage based on the presented records and generated modelled values which were based on the interaction between the two factors. The feedback process filtered out the wastage in the production system, and the actual usage values of lean production were generated. The associated losses that the factory's conventional practices incurred on powder materials, based on the ELTF model, were also generated. The values are model-based, and these could have their associated errors. The results of the multi variance analysis carried out on the monetary loss showed that a very small fraction of the actual usage had an effect on the factory profitability. This supports the fact already established that the majority of the actual usage recorded were wastages in one form or the other.

The underlining principle of lean technology is the elimination of waste in manufacturing processes. The econometric linear transfer function technique applied to the actual usage and actual loss data obtained filtered the waste in the production process and generated forecast values for actual loss and usage. This revealed, probably, that there had been poor manufacturing practices in the factory. The research findings could be used to control future wastage in the production system.

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APPENDIX

Appendix 1. Computations of the components of the classical econometric models

Months	Actual usage	Backshift operator	Loss	Backshift operator		
T	**X**	**Bx**	**Y**	**By**	**Byxt**	**BxYt**
1	1218236	-	7,668	-	-	-
2	1196386	1.018263336	15,407	0.497695853	595436.3502	15688.38322
3	1607255	0.744366015	6,255	2.46314948	3958909.318	4656.009426
4	1418981	1.132682538	2,278	2.745829675	3896280.138	2580.250821
5	2023204	0.701353398	12,599	0.180808001	365811.4701	8836.35146
6	1743550	1.16039345	(1,772)	-7.110045147	-12396719.22	-2056.217194
7	2063445	0.844970426	(7,462)	0.237469847	490005.9689	-6305.169316
8	2084695	0.989806662	7,097	-1.051430182	-2191911.243	7024.657883
9	2076993	1.003708246	2,167	3.27503461	6802223.96	2175.035768
10	2236369	0.92873448	1,202	1.802828619	4031790.036	1116.338845
11	2063346	1.083855543	5,313	0.226237531	466806.3038	5758.524502
12	1648745	1.251464599	1,867	2.845741832	4691902.616	2336.484406
13	2096898	0.786278112	16,496	0.113178952	237324.7191	12970.44373
14	1691511	1.239659689	701	23.532097	39804800.94	869.0014419
15	1847580	0.91552788	299	2.344481605	4331617.324	273.742836
16	1828905	1.010211028	5,076	0.058904649	107731.0077	5127.831178
17	1901645	0.961748907	2,990	1.697658863	3228344.488	2875.629232
18	1571001	1.210467084	3,954	0.756196257	1187985.076	4786.186852
19	1853567	0.847555551	677	5.840472674	10825707.41	573.795108
20	1951443	0.949844295	292	2.318493151	4524407.229	277.3545341
21	2199546	0.887202632	9,720	0.030041152	66076.8963	8623.609581
22	2109323	1.04277344	9,421	1.031737607	2176267.865	9823.968575
23	2079250	1.014463388	15,718	0.599376511	1246253.611	15945.33554
24	1367515	1.520458642	24,650	0.637647059	871991.9176	37479.30553
25	2051319	0.666651554	(3,947)	-6.245249557	-12810999.08	-2631.273685
26	2480818	0.826872024	(6,731)	0.586391324	1454730.151	-5565.675591
27	1229067	2.018456276	1,354	-4.971196455	-6109933.513	2732.989798
28	2608108	0.471248507	(8,903)	-0.152083567	-396650.3686	-4195.525454
29	2213454	1.17829781	(7,471)	1.191674475	2637716.633	-8803.062936
30	2367885	0.934781039	(2,782)	2.685478073	6358903.248	-2600.56085
31	1900368	1.24601393	2,013	-1.38201689	-2626340.674	2508.226041
32	2332573	0.814708907	17,624	0.114219246	266424.7304	14358.42978
33	2665198	0.87519689	17,578	1.002616907	2672172.577	15384.21093
34	2684588	0.99277729	1,980	8.877777778	23833175.69	1965.699035
35	2640031	1.016877453	11,931	0.165954237	438124.3299	12132.3649
36	2125469	1.242093392	5,278	2.260515347	4804655.293	6555.768923
37	2807444	0.757083311	19,646	0.268655197	754234.4208	14873.65874
38	2512192	1.117527641	4,335	4.53194925	11385126.65	4844.482325
39	3155650	0.796093356	(25,757)	-0.168303762	-531107.7668	-20504.97658
40	2960672	1.065855995	862	-29.88051044	-88466390.61	918.7678676
41	3063147	0.966545843	1,287	0.66977467	2051618.27	1243.9445
42	2790268	1.097796699	1,726	0.745654693	2080576.429	1894.797103
43	2830172	0.985900504	2,000	0.863	2442438.436	1971.801007
44	2883472	0.98151534	3,609	0.55417013	1597934.054	3542.288861
45	2986076	0.965639187	4,546	0.793884734	2370600.15	4389.795743
46	3245798	0.919982081	29,160	0.155898491	506015.0106	26826.6775

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Appendix 1. Computations of the components of the classical econometric models (continued)

Months	Actual usage	Backshift operator	Loss	Backshift operator		
T	**X**	**Bx**	**Y**	**By**	**Byxt**	**BxYt**
47	2571803	1.262071006	6,197	4.705502663	12101625.86	7821.054026
48	2139536	1.202037732	1,544	4.013601036	8587243.907	1855.946258
49	3356131	0.637500741	25,184	0.061308767	205760.2551	16054.81867
50	3302996	1.01608691	24,186	1.041263541	3439289.311	24575.07801
51	3957446	0.834628192	3,639	6.64633141	26302497.65	3037.211991
52	3040356	1.301639019	3,312	1.098731884	3340536.076	4311.02843
53	3579473	0.849386488	3,956	0.837209302	2996768.093	3360.172946
54	3815179	0.938218888	5,155	0.767410281	2927807.59	4836.518369
55	2957342	1.290070273	3,296	1.56401699	4625333.134	4252.071618
56	3861317	0.765889462	(6,613)	-0.498412218	-1924527.572	-5064.827013
57	3628468	1.064172813	1,388	-4.764409222	-17287506.4	1477.071865
58	3877466	0.935783318	2,270	0.611453744	2370891.105	2124.228132
59	3084324	1.257152621	4,484	0.506244425	1561421.829	5637.072352
60	3003163	1.027025173	3,776	1.1875	3566256.063	3878.047054