
**RELIABILITY COST ASSESSMENT OF SMALL-SCALE
PRODUCTION SYSTEM UNDER A SERIES COUPLED POWER
SUPPLY AND PRODUCTION MACHINE**

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Bayelsa State, Nigeria. Email Id: owufu@fuotooke.edu.ng**ABSTRACT**

Uncertainties in the parameters of a business, if not properly modeled in a net profit formation, could lead to false or illusive profit reporting. Most business owners pay less attention to the extent of the variability of some parameter, thereby exposing their business to future liquidation. In this study, a series reliability analysis and modeling of a variable power supply days and machine downtimes, alongside their alternative sources of remedy for failure, is done in formulating the annual net profit of Celo Expert Company. The developed annual net profit model gives a net profit of ₦156,054,531, and an inaccurate approach gives a net profit of ₦180,353,467, with a difference of ₦24,297,936. Projecting business future expenditure on such illusive profit could result in indebtedness or interrupted production process due to the lack of funds for purchase of materials and payment for services rendered.

KEYWORDS: Reliability, Failure Rate, Illusive Profit, Liquidation, Exponential Distribution, Poisson Distribution, Probability.

INTRODUCTION

Many seemingly thriving businesses in some local and non-sophisticated environments, small skill businesses inclusive, analyze progress on everyday activities of continuous sales, production operation, a non-obvious indebtedness, and most uninformedly amongst others unfounded claims of "as long as the facility is open for business" Ayandibu and Houghton, (2017).

Critical economic-driven analysis suggesting regular comparison of income with expenditure over time, with expenditure involving cost incurred on expendables and non-expendables,

may put net profit on a lean margin and project future liquidation (Osei-Assibey 2015 and Yusuf and Essien 2018).

The reliability of power supply and that of the production machines could sometimes be overlooked in business profit analysis, which often leads to the frenzy of gross and the silence on net, which unarguably represents the financial health status of any organization (Mitchell and Feid, 2000, Maseko and Miani, 2011 and Ezejifor et al., 2014). Power supply, whether national grid supply or privately owned, is quite expensive, so also is the maintenance of production machines and tools. Perhaps because these two requirements are vital to smooth production process, so much is provided to ensure their sustenance. Reliability study of power supply to a facility and that of the production machine will elicit how much downtime is needed to be averted with the attendant preventive cost.

For some reasons of lack of proper reliability assessment some organizations becomes reactive to prevent cost, necessitating financial solutions that are best funded from the profit on current production, hence preventing an appreciation of the cumulating effect with time. The side effect of this kind of planning is that resources are not properly deployed, hence crucial sectors might suffer the backlash, consequently affecting productivity negatively (Maseko and Miani, 2011). Reliability of power supply system, which has to do with studying the probability of power supply or otherwise for a given period of time, made one to evaluate the likely periods of power supply and the likelihood of the period of no power supply, such as to make projections for alternative supply and properly streamline and assign resources for this purpose.

On the other hand, the reliability assessment of production machines gives an idea of machine availability and downtimes to enable for proper maintenance planning. Although power supply and production machines can be seen as separate units of the entire production system, but the functional interrelationship between them allows one to couple them in a series connection, such that if one of the units (power supply or production machine) fails, the entire system in terms of production process fails (Nahmias 2009, Zio 2007). The above disposition on series component reliability is held in this study to aggregate the preventive cost of power failure and machine break down time against organization's major expenditure per unit time in assessing the net profitability or otherwise of a small-scale production unit to forestall future bankruptcy and liquidation.

2.0 MATERIALS AND METHODS

The materials sourced and the methodology adopted in this study to achieve the set goal are presented below.

2.1 Materials

Primary data on power supply and machine failure time were sourced from Celo Expert Company located in Yenagoa, Bayelsa State of Nigeria. The company undertakes the cutting and sealing of cellophane into packing bags and relies on a national grid (public) power supply and a private power supply arrangement. The public power supply comes at a cost of ₦2,500,000 per week, assuming no power failure per week, with each failure day accounted for with a private supply at a cost of ₦150,000 per day. The small-scale production company works for 5 days per week and operates from a rented facility with an annual rent of ₦3,200,000. Each monthly production run cost and all other expenditure, except for power supply and machine downtime cost, amounts to about ₦2,800,000, with a gross profit of ₦34,600,000.

For every machine breakdown, a machine is hired at a cost of ₦50,000 per day, with the caveat to fix all originating failures while on hire, with such cost inclusive of the hiring cost. The company's production machine is perceived to have entered the aging (wear and tear) state of its life cycle, resulting in frequent breakdowns. There are five personnel with annual salaries of ₦8,347,533 before tax.

2.2 Methodology

The method adopted in this study is that of a mathematical modeling of the joint series reliability distribution of the power supply and production machine, and a numerical analysis for cost justification to proceed with production operation or otherwise.

3.0 Model Development

Consider the operation of a small-scale production company for a period of one year such that its expenditure on a production run including cost of materials and labor in Naira is (₦K) and the number of production run (N) are known. Let the fixed cost on rentage per annum be (₦S), the weekly cost of power supply be (₦p) assuming no power failure per week, machine hiring cost per day be (₦O), alternative power supply for public power supply failure be (₦θ) per day, and the gross profit on each production run be (₦C) and the total personnel cost be S_c .

The issue for concern in the build-up to the design of a solution mechanism for the true financial status of this company is having the history of the number of times per week of the 73 weeks per year of power supply or otherwise, and the failure rate of the production machine per week, to be able to track the incurred cost of these failures based on their likelihood of occurrence.

Let the number of days of public power supply failure per week be a random variable X , with realizations $(x = 0, 1, 2, 3, \dots, b)$ such that the expected value of the random variable is \underline{X} .

Since the realizations of the random variable takes up discrete values (number of times of public power supply failure) and the time between failures could be approximated with an exponential distribution, it implies that the variable describing the number of times of power failure per week could be approximated with a Poisson distribution, being a discrete probability distribution of independent, identical exponential random variables (Nahmias 2009).

Suppose we introduce a stochastic process $A(t)$ defined as the number of power supply failures that occur up till time t (one week), then the probability (Pr) that the number of failures that occur in a week will be equal to n can be represented according to Nahmias (2007) as:

$$P \{A(t) = n\} = P \{A(t) < n + 1\} - P \{A(t) < n\}$$

$$= \frac{e^{-\underline{X}}(\underline{X})^n}{n!} \dots\dots\dots 1$$

Where $\underline{X} = E(X) = \sum_{i=1}^b xPr(x) \dots\dots\dots 1b$

Similarly, let the time to failure of the production machine be a random variable T such that it has a realization t and the random variable follows an exponential distribution.

Supposing the number of failures of the machine, unit time (per week in this case) is λ then the mean failure time is (λt) and the probability (Pr) that the machine will survive beyond time t before failure also know as the reliability $R(t)$ distribution function according to Barlow and Proschan (1965), Zio, (2007) and Nahmias (2009) is;

$$R(t) = e^{-\lambda t} \dots\dots\dots 2$$

Where $(\lambda t) = E(T) = t.Pr Pr(t) \dots\dots\dots 2b$

In the same vein, the probability that the machine will fail on or before a given time t (a week in this case) is given accordingly as:

$$F(t) = 1 - e^{-(\lambda t)} \dots\dots\dots 3$$

Where $F(t)$ = The cumulative distribution of failure.

Assuming the firm does not render any other service but relies strictly on its product for profit making, then its annual net profit (P_N) has the components of Annual gross profit (G_p) and Annual expenditure (A_E). The Annual expenditure has the component of the fixed cost A_{FE} (rentage + production run cost) and power supply cost E_{PS} , machine hiring expenditure E_m and the personnel Expenditure (E_p).

Given the above costs components, the annual net profit (P_N) can be expressed as:

$$P_N = G_p - A_E \dots\dots\dots 4$$

$$\text{Where } A_E = A_{FE} + E_m + E_p + E_{sp} \dots\dots\dots 5$$

The weekly power supply cost function $W_c(x)$ is given as:

$$W_c(x) = \{\rho, \quad \text{if } x = 0 \quad \rho + x\theta, \text{ if } x > 0 \dots\dots\dots 6$$

The expected weekly power supply cost is given as;

$$E[W_c(x)] = \sum_{x=0}^b Pr(X=x) \cdot (\rho + x\theta) \dots\dots\dots 7$$

$$= \sum_{x=0}^b Pr(X=x)\rho + x \sum_{x=0}^b Pr(X=x)\theta$$

$$\text{But } \sum_{x=0}^b Pr(X=x) = 1 \text{ and } x \cdot \sum_{x=0}^b Pr(X=x) = \lambda = \underline{X}$$

$$\text{Hence } E[W_c(x)] = \rho + \theta \underline{X} \dots\dots\dots 8$$

$$\text{The annual expected cost } E[W_c(x)]_A = N_{WA}[\rho + \theta \underline{X}] \dots\dots\dots 9$$

Where N_{WA} is the number of weeks per annum

The machine operational cost per annum is formulated as follows:

Given that the mean time to failure of the machine is \underline{T} , then

$$\lambda_m = \frac{1}{\underline{T}} \dots\dots\dots 10$$

Where (λ_m) is the number of machine breakdown per month.

The expected breakdown per year (λ_y) is

$$\lambda_y = \lambda_m \times 12 \dots\dots\dots 11$$

Since the cost per day for hiring a machine for a day downtime is $N\phi$, then let the daily failure rate be λ_d .

Such that $\lambda_d = \frac{\lambda_m}{N_m}$ 12

Where N_m is the number of days in a month for the organization’s monthly operation.

Then, the probability (Pr) that the machine will fail in one day i.e Pr {T ≤ 1 day} is given as:

$Pr \{T \leq 1 \text{ day}\} = 1 - e^{-\left(\frac{\lambda_m}{N_m}\right)}$ 13

Hence the annual hiring cost of a machine by the firm E_m is:

$E_m = \phi \left[1 - e^{-\left(\frac{\lambda_m}{N_m}\right)} \right] N_y$ 14

Where N_y is the number of days in a year by the firm operation.

The fixed cost expenditure (A_{FE}) of the firm’s annual expenditure is given as;

$A_{FE} = (K.N) + \delta$ 15

The gross profit G_p is given as ;

$G_p = (C.N)$ 16

And the personnel cost E_p is given as;

$E_p = S_c$ 17

Substituting eqn (9), (14), (15), (16) and (17) in eqn (4) gives

$P_N = (C.N) - [N_{WA}[\rho + \theta X] + \phi \left[1 - e^{-\left(\frac{\lambda_m}{N_m}\right)} \right] N_y + (K.N) + \delta + S_c]$ 18

$P_{NI} = (C.N) - [N_{WA}\rho + (K.N) + \delta + S_c]$ 19

Where P_{NI} is the perceived annual net profit from inaccurate estimation.

4.0 RESULTS, CALCULATION AND DISCUSSIONS

4.1 RESULTS

The history of the weekly public power supply to celo Expert company per annum indicating the number of days of power supply failure per week to the company is shown in table 4.1

Table 4.1: Days Per Week of Power Supply Failure to Celo Expert Company

0	3	3	2	1	0	4	1	1	3
3	1	1	1	3	1	2	4	4	1
2	2	2	5	1	3	1	2	2	2
0	1	5	0	2	1	3	3	3	4
1	4	1	4	4	2	5	2	3	3
2	2	2	1	1	4	2	1	3	2
1	1	0	0	5	2	4	2	4	1
4	4	2							

Similarly, the annual machine failure time per month is given in table 4.2

Table 4.2: The machine time to Failure in Months Per Annum

5	4	5	5
5	5	4	4
4	3	3	5

Given that the firm operates 5 working days, it has 20 days per month i.e. $N_m = 20$ days/month, $K = \text{₦}2,800,000$, $N = 12$ months, $\delta = \text{₦}3,200,000$, $\theta = \text{₦}150,000$ per week, $\phi = \text{₦}50,000$ per day, $C = \text{₦}34,600,000$ per year, $\rho = \text{₦}2,500,000$, $N_{WA} = 73$ Weeks/year, $N_{WM} = 6.08$ weeks/month, $N_y = 364.8$ days/year, $S_c = \text{₦}8,347,533$.

From the entries in Table 4.1, the weekly number of days of supply failure does not follow a discerning order, hence it is a random variable (X), with a realization

$$x = 0, 1, 2, 3, 4, 5.$$

From eqn. (1b)

$$\underline{X} = \lambda = 0 \times 6/73 + 1 \times 20/73 + 2 \times 19/73 + 3 \times 12/73 + 4 \times 12/73 + 5 \times 4/73$$

$$\simeq 2.2 \text{ days/weeks}$$

Hence from eqn. (1), the probability that the number of days of supply failure per week is zero (uninterrupted power supply) i.e. $\Pr \{A(1 \text{ week}) = 0\}$ is :

$$\Pr \{A(1 \text{ week}) = 0\} = \frac{e^{-2.2} (2.2)^0}{0!} = 0.111$$

From eqn. (9),

$$E_{ps} = N_{WA} [\rho + \theta \underline{X}]$$

$$\Rightarrow E_{ps} = 73 [2,500,000 + 150,000 \times 2.2]$$

$$= 73 [2,500,000 + 330,000]$$

$$= 73 [2,830,000] = \text{₦}206,590,000$$

The gross profit from eqn. (16) is:

$$G_p = \text{₦}34,000,000 \times 12 = \text{₦}408,000,000$$

The fixed cost expenditure (A_{FE}) of the firm's annual expenditure from eqn. (15) is;

$$A_{FE} = (2,800,000 \times 12) + 3,200,000 = \text{₦}36,800,000$$

The personnel cost from eqn. (18) is;

$$E_p = \text{₦}8,347,533$$

Given the entries of table 4.2, the time to failure of the machine in months per annum (T) is a random variable, with realization $t = 3, 4, 5$. Hence from eqn. (2b), the mean time to failure (\underline{T}) is given as;

$$\begin{aligned}\underline{T} &= E(T) = 3.2/12 + 4.4/12 + 5.6/12 \\ &= 0.5 + 1.33 + 2.5 = 4.33 \text{ months}\end{aligned}$$

Since $\underline{T} = 4.33 \text{ months}$, the value of the failure rate of the machine per month from eqn. (10) is:

$$\lambda_m = \frac{1}{\underline{T}} = \frac{1}{4.33} = 0.23 \text{ failures/month.}$$

The expected breakdown per day from eqn. (2) is:

$$\lambda_d = \frac{0.23}{20} = 0.0115 \text{ failure/day}$$

Hence from eqn. (14), the machine hiring operation cost E_m per annum is given as;

$$\begin{aligned}E_m &= 50,000[1 - e^{-0.015}]364.8 \\ &= 50,000 [0.0114] 364.8 \\ &= \text{₦}207,936.\end{aligned}$$

The net profit per annum P_N from eqn. (18) is given as;

$$\begin{aligned}P_N &= 408,000,000 - 206,590,000 + 207,936 + 36,800,000 + 8,347,533 \\ &= 408,000,000 - 251,945,469 \\ &= \text{₦} 156,054,531\end{aligned}$$

A possible inaccurate estimation of the annual net profit P_{NI} of the firm from eqn. 19 is given as;

$$\begin{aligned}P_{NI} &= (C.N) - [N_{WA}\rho + (K.N) + \sigma + S_c] \\ &= 408,000,000 - [2,500,000 \times 73 + 2,800,000 \times 12 + 3,200,000 + 8,347,533] \\ &= 408,000,000 - 227,647,533 \\ &= \text{₦} 180,352,467 \\ P_{NI} - P_N &= \text{₦} 24,297,936\end{aligned}$$

4.0 DISCUSSION

From the calculation it was determined that the mean number of days of supply failure was 2.2 days/week, which accounted for a weekly alternative power supply expenditure of ₦ 330,000 and ₦24,090,000 per annum of 73 weeks. Similarly, the failure rate of the machine per day was estimated as 0.014 failure, which accounted for an expenditure of ₦207,936 per

annum. Since the power supply failure and that of the machine may not occur regularly, there is a likelihood of improper account of the expenditure of alternative sources, hence, the omission of these expenditure terms in the perceived net profit of the inaccurate model. Perhaps, what could best be referred to as a good accounting system in some business environment taking proper account of failure alternative cost could possibly reduce the net difference by 50%, which still creates a false impression of an annual net profit or illusive profit.

5.0 CONCLUSION

The importance of an accurate mathematical modelling of an accounting system for profit evaluation in a stochastic business environment that allows for reliability assessment of some variable profit parameter has been considered in this study. Net profit comparison for an accurate and inaccurate modelling of profit system has shown that a firm can celebrate a profit that is unrealized or illusory, thereby leading to indebtedness on the long run.

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