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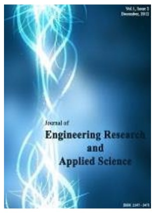

Annual Running Cost as Dominant Feature for Industrial Machines Available Annual Running Cost Budget Allocation

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Abstract

The annual running cost of a machine, which includes expenses like depreciation, repairs, maintenance, fuel, and operator wages, significantly impacts profitability, operational efficiency, and decision-making. Increased running costs can reduce profits, strain budgets, and potentially lead to decreased equipment utilization. Conversely, managing and reducing these costs can improve efficiency and competitiveness. This study found annual running cost as strong decision strategy for machine vendors' selection pre procurement. A low purchase cost and good engineering factors machine may pay heavily for these when running the machine. Hence the need for its consideration after vendor might have passed both the machine low cost and the engineering features requirements. In other to proffers solutions to this, this study identified the attributes to this strategic decision, modeled it (mathematics logics and is algorithm development) and developed a software decision tool using python programming language for its application. Three machines were used as case studies in selected Cocoa processing Industry (Winnowing Machine (W/M), Cocoa Milling Machine (M/M) and Cocoa Liquor press (L/P) for extracting butter from the liquor . Concerning Winnowing Machine (W/M), the line with diamond shape points, was observed that the machine annual operating cost kept increasing gradually as the machine kept aging. This was as a result of frequent increase in repair and maintenance cost. The increase was pronounced well after the third year of purchase (2010) And in most cases the machine was over flogged. The Milling machine with square points shaped (M/M) was found sharp MAOC value It was observed the machine has a long time down time in 2013 due to costly damaged of critical component , the same issue was about to occur in 2015 but the experienced of 2013 helped to rectify the problem at infancy. The liquor press with pyramid shape points (L/P) really performed excellently well but dropped little at year 2015 , here it was observed that the machine was underutilized the cocoa crushing rate for the year was less compared with the initial targets of the company. Using the running cost fund available (N12,370,000:000) budgeted for the three factory machines, that of the winnowing machine (WM) was N4,557,815.874 which is the highest, followed by that of Milling Machine (MM) N 3,927,734.660 and that of the liquor press (LP) was N3,901,550.731 the list, based on available financial running cost capability of the company of Twelve Million ,three hundred and seventy (N12,370,000) Naira only. This model will be found usable in allocating available running cost allocation to several machine in small, medium and large-scale industries.

Keywords: *Strategic decision, machine running cost attributes, model development, budget allocation.*

1. Introduction

Operating Costs Operating costs generally include those costs that are incurred as a direct result of the machine being used. These costs vary as machine use varies [1] Industrial machinery costs and production costs are figures necessary for the successful operation of a manufacturing business. For a company to be profitable, its product must generate more revenue than it costs to produce [2] Companies then must evaluate their total expenses with accuracy and confidence to achieve profitability. Machine vs. production costs factor into the overall expenses of running a company. Neither cost should be calculated in isolation but considered as a part of a larger equation. Production costs represent the total expenses related to the operational costs of doing business as a company, while industrial machinery costs are those expenses related to the means of making the product. The operating costs of each are determined by combining fixed and variable costs calculated at yearly and hourly rates [3].

Machinery procurement is a multi-objective problem because of its complex variables such as purchase cost, operating cost, machine capacity, due –date delivery, installation and commissioning cost,

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maintenance cost, overall machine effectiveness, freight and handling cost, salvage cost, reliability of machine, vendor's attitude and special consideration, vendor's competence and ability, financial investment appraisal, accuracy or precision of machine, human reliability, maintainability , and so forth all these special effect there negative effects on production profits of a company if they were not properly managed. The dominant of the all is the machine running cost [4] and [5].The annual operating cost of industrial machinery is part of a broader equation affected by two distinct types of costs, fixed and variable. Where one cost is a certain amount, the other can fluctuate. Fixed costs remain the same even as production volume rises or falls. Variable costs do not. Such costs increase or drop with the volume of production [6] and [7]. This is the financial economic consideration required to run the processing machine through the year. The model used is as summarized below from [8]. Attributes for the computation were identified by this author as well as[9] ,as cost related to machine purchase, utilization, repair and maintenance , labor rate, volume of oil used, fuel consumption and attached accessories used by the procured machine.

Running costs refer to the continual expenditure required to operate, maintain, and ensure the proper functioning of a fixed asset. These costs are essential for the asset to generate output over its useful life. Examples of running costs include power, maintenance, consumable materials for machinery, and fuel, oil, tires, and servicing for motor vehicles [10] and [11]. Manufacturing Equipment requires: Power (The electricity needed to run the machines), Maintenance (Regular servicing to prevent breakdowns and prolong the life of the equipment.) and Consumable Materials (Lubricants, oils, and other materials required for the smooth operation of machinery [5] and [2]. Running costs are crucial for budget planning and financial forecasting [12]. They are instrumental in determining the total cost of ownership of a fixed asset and impact the profitability and operational efficiency of a business. Hence, the research improved on the existing model for selecting machine of high and low running cost equipment decision making.

While there's no single "first" for everyone, mathematical logic is often considered a foundational prerequisite for understanding algorithms, with algorithms themselves being a practical application of logic and mathematics [13] and [7]. Algorithms should be learned after grasping fundamental mathematical logic concepts, which in turn, often builds upon basic mathematical principles. [14], stated that the estimates for manufacturing machinery maintenance costs have a wide range from 15 % to 70 % of the cost of goods produced. The literature, typically, uses varying metrics and range in their estimates. For instance, [15] estimates that industrial maintenance is 5.5 % of company turnover (i.e., sales) but it ranges from 0.5 % to 25 %. Other research estimates that maintenance is 37.5 % of the total cost of ownership [16]. Along with the variation in metrics, the literature on maintenance costs varies by country and industry of study, making it difficult to compare and generalize. Hence this research developed its models for estimating annual running cost for the decision making. Which led to the mathematical logic required.

Mathematical Logic: provides the framework for reasoning and constructing proofs, which are crucial for understanding how algorithms work and why they are correct. Examples are: propositional logic, predicate logic, set theory, and mathematical proof techniques are all part of mathematical logic. Why it comes first is that understanding logical concepts allows you to analyze algorithms, identify potential flaws, and prove their correctness [17].

2. Methodology

2.1. Models Development for Machine Annual Operating Cost

The models developed required machine annual operating/running cost, put into consideration financial economic consideration required to run the processing machine throughout the year.

Table .1: Machine Annual Operation Cost $\left[\dddot{O}_c\right]$ and their Attributes

S/N	Strategic Decision	Attributes
1.	**Economics Feature Used:** Machine Annual Operation Cost $\left[\dddot{O}_c\right]$	a. Annual Fixed Cost b. Machine Utilization Cost c. Maintenance cost d. Labour Rate e. Cost of Total Oil Utilized f. Cost of Total Fuel Utilized / Electric Bill Received.

2.1. Machine Annual Operating/Running Cost $\left[\ddot{O}_c\right]$

This is the financial economic consideration required to run the processing machine throughout the year. The model used was adopted from Hunt (1973) modification to this model was carried out by Akinnuli [8].

$$\left[\ddot{O}_c\right] = Fe\%P + U\left(RM_c + L + O + F + T\right) \quad (1)$$

Where: Fe% is % (Taxes + Insurance + Shelter)

$$\left[\ddot{O}_c\right] = 0.015P_c + 0.0025P_c + 0.01P_e = 0.0275P_c/\text{yr or } 2.75\%P_c \quad (2)$$

2.2. Determination of Machine Utilization Cost U_{mc} Cost of Machine Utilization "U"

This is ratio purchased cost divided by the life span of the machine.

$$\text{Umc is } P_c/L_s \quad (3)$$

where: U is machine utilization, P_c is machine purchased cost, L_s is machine's life span.

2.3. Determination of the and Maintenance Cost [RM_C]

$$\left[RMc\right] = 0.06P_c / Hr \times Hp \quad (4)$$

where: P_c is the purchase cost of the machine per hour rate of usage and H_p is the horse power.

2.4. Determination of the Labour Rate (L_r)

This is salary of operator paramount divided by total operation of hour.

$$Lr = S_o / T_{oh} \quad (5)$$

Where Lr is the labour rate, so is salary of operator per month, T_h is total operating hour.

2.5. Determination of Total Oil Volume Cost (O_c)

This is product of total oil volume used per month, cost year litre of oil and number of months in a year.

$$Oc = \left[TO_v \times O_{CL} \times 12\right] \quad (6)$$

Where: O_c is oil cost, TO_v is total volume of oil used per month, O_{cL} is of a litre of oil 12 is number of months in a year.

2.6. Determination of the Total Fuel Cost Consumed

$$If_c = \left[Tf_v \times Fcl \times 12\right] \quad (7)$$

Where: Tfc is total annual fuel cost, Tf_v is total volume of fuel used 12 is total number of months in a year.

2.7. Determination of Cost of Attached Accessory Used by the Machine per Hour (Tc)

$$Tc = Ac / P_o \quad (8)$$

where: T_c is the cost of accessory per hours used by the machine, A_c is the purchased cost of the accessory attached to the machine and P_o is the operating period of the accessory in hours.

$$\left[\ddot{O}_c\right] = Fc\%P + U\left(RM_c + h_r + O_c + Tf_c + T_c\right) \quad (9)$$

Modifications: If electrical energy is used to power the machine there is no fuel consumption and pit work be of little or no value. Therefore, in the equation;

$$O_c + Tf_c = E_c \quad (10)$$

Where E_c is Energy cost per hour E, Cost of Energy per month (Bill)/Total Hour of Operation per month. The new equation became;

$$\left[\ddot{O}_c\right] = Fc\%P + U\left(RM_c + L + E_c + T\right) \quad (11)$$

Equation (11) (Modified) by Akinnuli [10];

Summary of Machine Annual Operation Costs and Modifications;

(a). If fuel driven engine, and not self-propelled;

$$\left[\ddot{O}_c\right] = Fc\%P + J\left(RMP + L + O + F + T\right) \quad (12)$$

(b). If fuel driven engine and self- propelled, T = O

$$\left[\ddot{O}_c\right] = Fc\%P + J\left(RMP + L + O + F + Ec\right) \quad (13)$$

(c). If electrically driven engine and not self-propelled, O + F = Ec

$$\left[\ddot{O}_c\right] = Fc\%P + J\left(RMP + L + Ec + T\right) \quad (14)$$

(d). If electrically driven engine and self-propelled, T = O

$$\left[\ddot{O}_c\right] = Fc\%P + J\left(RMP + L + Ec\right) \quad (15)$$

Cost of Energy Consumer by each Machine

$$E_c = \left[\frac{(\text{Total Fuel Cost} + \text{Total Oil Cost}) + \text{Electric Bill Reserved}}{\text{Total Energy Consumed by Plant}}\right] x \text{ Machine Energy Consumed}$$

2.8. Determination of the Required Value to Run Each Machine Based on Available Running Cost for the Year

Total average of the number of machines considered machines (T_{av})

$$(T_{av})_n = (M_{1av} + M_{2av} + M_{3av} + \ldots + \ldots + M_{nav})\, n \quad (16)$$

Where:

$(T_{av})_n$ is the summation of averages of each machine for the period of years used.

$(M_{1av} + M_{2av} + M_{3av} + \ldots + \ldots + M_{nav})$ is averages of each machine for the period of years considered n is the total number years for the period of the running cost.

2.9. Determination of Fractional Contribution of Each Machine to the Total Average

Machine fractional contribution ($M_{f\,n}$).

$$M_{f\,n} = T_{av} / M_{avn} \quad (17)$$

Where is $(T_{av})_n$ is the summation of averages of each machine for the period of years used as in equation (16).

2.10. Annual Machines' Data Collected

Total data sufficient available for collection for this research ran for a span of ten (10) years (2008 to 2017) and average of each variable for the machine annual operating cost calculation was computed as shown in the table 2.

Table .2 Average Data for Machine Annual Operating Cost Input 2017 – 2024

S/N	Parameters	Winnowing Machine (WM)	Milling Machine (MM)	Liquor Press Machine (LP)
[A]	Machine Annual Operation Cost (MAOC)			
(1)	P_c: Machine Purchase Cost	9,560,000	7,394,000	15,280,000
(2)	L_s: Machine Life Span	62,400 Hrs	58,700 Hrs	55,600 Hrs
(3)	H_p: Operating Hour per annum	6,240 Hrs	5,870	5,5,60
(4)	S_o: Salary of Operator per month	120,000	120,000	120,000
(5)	T_{oh}: Total Operation Hour	520	485	460
(6)	T_{Qr}: Total Volume of Oil used per month	30 litres	30 litres	30 litres
(7)	O_{cl}: Cost per liter of Oil	1,400	1,400	1,400
(8)	T_{fv}: Total Final Volume/year	150 litres	150 litres	120 litres
(9)	F_{cl}: Fuel Cost per Litre	₦220	₦220	₦220
(10)	A_c: Machine T_c Accessory Cost	₦4.34kg/Hr	₦4.34kg/Hr	₦4.34kg/Hr
(11)	K_c: Operating period of accessory in hours	20 hrs	20hrs	20hrs
(12)	% Tax: Percentage Tax Cost	0.015 P_c	0.015 P_c	0.015 P_c
(13)	% Ins: Percentage of Insurance Cost	0.0025P_c	0.0025P_c	0.0025P_c
(14)	% S_h: Percentage of Shelter cost	0.01 P_c	0.01 P_c	0.01 P_c

Table 3. Windowing Machine

S/N	AOC	MAOC
1	226061365.2	1.0000
2	234536333.2	1.0375
3	255735333.2	1.1313
4	256678487.2	1.1354
5	278272629.2	1.2310
6	297837365.2	1.3175
7	298761553.2	1.3216
8	315673833.2	1.3964
9	317365433.2	1.4039
10	345721365.2	1.5293

Table 4. Milling Machine

S/N	AOC	MAOC
1	169482810.4	1.11
2	164567849.5	1.0778
3	169146356.2	1.1078
4	165888564.6	1.0865
5	170983554.6	1.1198
6	169368297.8	1.1093
7	169457783.4	1.1098
8	152685698.9	1
9	157873774.5	1.034
10	161909875.7	1.0604

Table 5. Liqour Press Machine

S/N	AOC	MAOC
1	499256498.3	1.0787
2	489754816.9	1.0582
3	501345678.4	1.0832
4	478312045.9	1.0335
5	491464985.7	1.0619
6	581536415.4	1.2565
7	482378951.4	1.0422
8	509685698.9	1.1012
9	462824896.5	1
10	475743958.6	1.0279

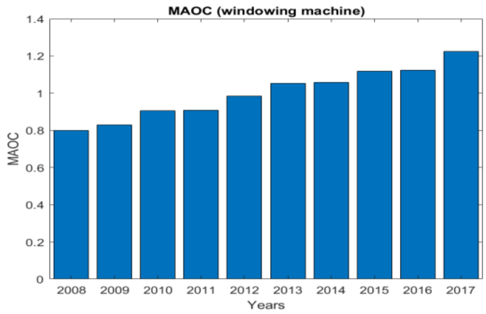

Figure 1. Winnowing Machine (MAOC)

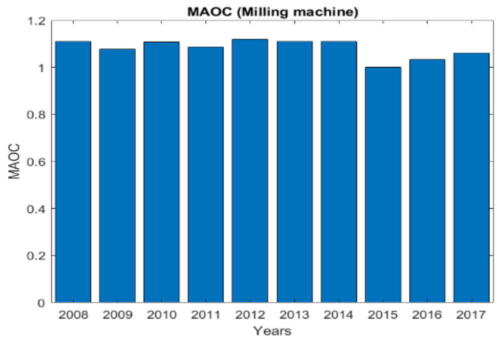

Figure 2. Milling Machine (MAOC)

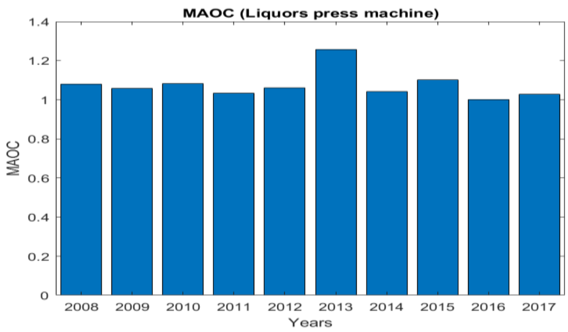

Figure 3. Liquor Press Machine (MAOC)

2.11. Models Applications

2.11.1. Machine Running Cost Index Determination

The identified attributes for the annual running cost determination were: annual fixed cost, machine utilization cost, maintenance cost, labor rate, cost of total oil utilized, cost of total fuel utilized / electric bill received. Inputting the collected data in Table 1 into the mathematical models developed these gave the results of machine annual operating costs for each machine under study as shown in Tables 3 ,4, and 5 respectively.

Figures 1, 2 and 3 shows the graphical performance analysis of the threemachine used as case studies. These are yearly performance of Cocoa Winnowing machine (W/M), Cocoa Milling Machine (M/M) and Cocoa Liquor Press Machine (L/P) as against their yearly annual operating costs**.**

Figure1 shows gradual increase in the annual running cost of winnowing machine as it is aging. Figure 2 shows nearly equal annual operating cost not until 2014 when the machine experienced low utilization period due to drop in quantity of materials to be processed. It picked up again 2015 to 2017. Figure 3 shows that the annual operating cost from 2008 to 2012 was nearly uniform not until 2013 when the machine experienced damage of one of its costly critical part, the same was about to happened in 2015, the experience of 2013 made the maintenance crew rectified the fault fast.

Comparing the final average computed in table 6, W/M (1.25039), M/M (1.08154), and L/P (1.07433). These shows that Winnowing machine has the greatest annual operating cost factor (index) followed by milling machine while the Liquor press has the list operating running cost index**.**

Table 6: Summary of tables 3,4, and 5 Using their performance indices for figure 4 development.

YEAR	**Machine Annual Operation Cost**		
	Winnowing Machine	Milling Machine	Liquor Press
2008	1.0000	1.11	1.0787
2009	1.0375	1.0778	1.0582
2010	1.1313	1.1078	1.0832
2011	1.1354	1.0865	1.0335
2012	1.2310	1.1198	1.0619
2013	1.3175	1.1093	1.2565
2014	1.3216	1.1098	1.0422
2015	1.3964	1	1.1012
2016	1.4039	1.034	1
2017	1.5293	1.0604	1.0279
AVERAGE	**1.25039**	**1.08154**	**1.07433**

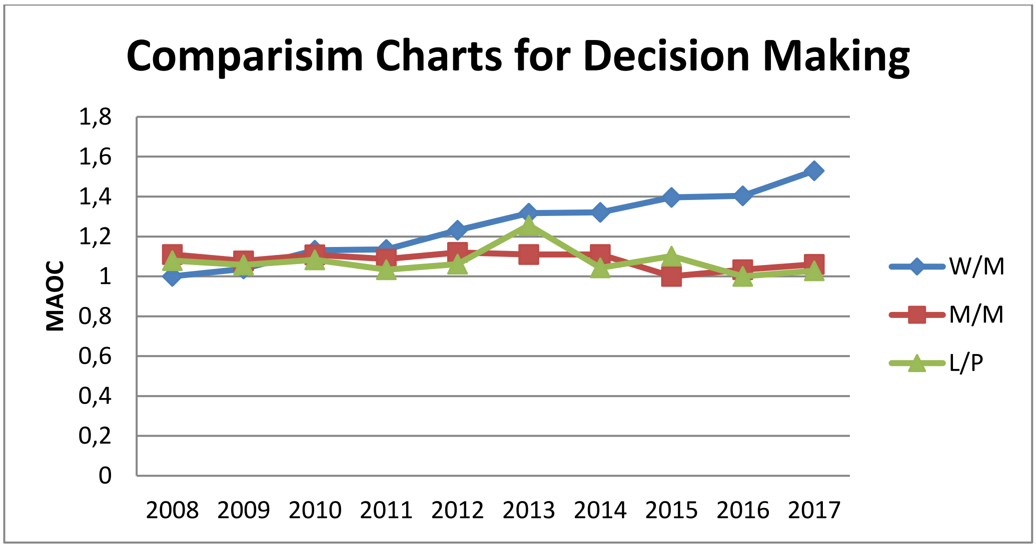

Figure 4. Graph for comparing the three Machines performance against their Machine Annual operating cost for the period of ten (10) years 2008 to 2017

This is to justify the claims written under figures 3,4, and 5 respectively, the plotted overlapping graphs in figure 4 really proved the claim right. Compared with the final average computed in table 6, W/M (1.25039), M/M (1.08154), and L/P (1.07433). These shows that Winnowing Machine (WM) has the greatest annual operating cost index followed by Milling Machine (MM) while the Liquor Press (LP) has the list operating cost index.

2.11.2. Determination of the Required Operating Running Cost for Each Machine Based on Available Running Cost (ARC) for the Year

The available running cost for the year is Twelve Million, three hundred and seventy Thousand (N12,370,000) Naira only.

Total average of the three machines;

$(T_{av}) = 1.25039 + 1.08154 + 1.07433 = \mathbf{3.40626}$

Percentage contribution of each machine to the total average:

Winnowing machine (W/M) = T_{av} / WM_{av}

Milling Machine (M/M) = T_{av} / MM_{av}

Liquor Press (L/P) = T_{av} / LP_{av}

Fractional contribution of winnowing machine;

$(WM_f) = [ARC / T_{av}] * W\,M_{av}$

$WM_f = [N12{,}370{,}000/3.40626] * 1.25039 =$ **4,557,815.874**

Fractional contribution of milling machine;

$(MM_f) = [ARC / T_{av}] * MM_{av}$

$MM_f = [N12{,}370{,}000/3.40626] * 1.08154 =$ **3,927,734.660**

Fractional contribution of liquor press;

$(LP_f) = [ARC / T_{av}] * LP_{av})$

$LP_f = [N12{,}370{,}000/3.40626] * 1.07433 =$ **3,901,550.731**

Table 7. Running cost available budget sharing allocation

S/N	MACHINE	AVAILABLE RUNNING BUDGET	MACHINE SHARE.
1	Winnowing machine (C_f)	N12,370,000	4,557,815.874
2	Milling machine (MM_f)	N12,370,000	3,927,734.660
3	Liquor press (LP_f).	N12,370,000	3,901,550.731
		TOTAL	**N12,370,000**

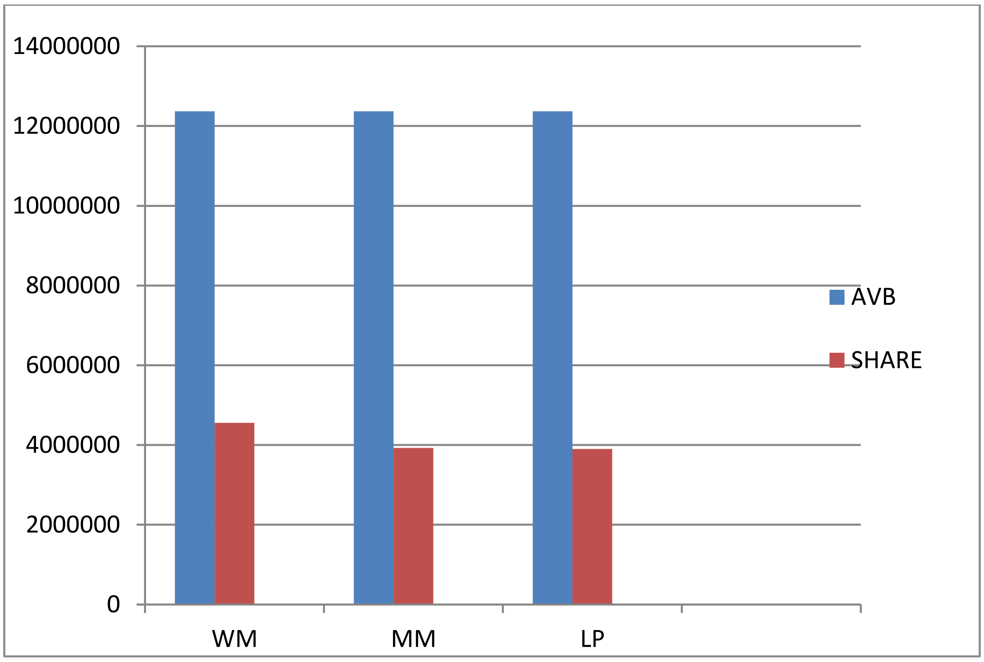

Figure 5. Fractional share of each machine in the available running cost

Using the running cost fund available (N12,370,000:000) budgeted for the three factory machines, that of the winnowing machine (WM) was Four million, five hundred and fifty seven thousands, eight hundred and fifteen Naira eight hundred and seventy four kobo (N4,557,815.874) which is the highest, followed by that of Milling Machine (MM), Three million nine hundred and twenty seven thousand ,seven hundred thirty four Naira, six hundred and sixty kobo (N 3,927,734.660) and that of the Liquor Press (LP) was Three million, nine hundred and one thousand, five hundred and fifty Naira, seven hundred and thirty one kobo (N3,901,550.731).

This figure 5 compared the shared fraction with the available running cost at glance to support the claim. This proved that winnowing machine required more running cost than Milling machine and Liquor press of the company.

3. Results

The required attributes were identified, models to the attributes were successfully developed. Applications of the developed models using the available data of selected three machines from cocoa processing industry (winnowing machine, milling machine and liquor press) Using available machine operation running cost budget of Twelve Million ,three hundred and seventy (N12,370,000) Naira for the three machines. The allocation running cost for each of this machine are : winnowing machine (WM) was N4,557,815.874 which is the highest, followed by that of Milling Machine (MM) N3,927,734.660 and that of the liquor press (LP) was N3,901,550.731 the list.

4. Conclusions

The method applied really proffers solutions to the identified gap in literature. The attributes were identified, their respective models were developed. The developed models when applied gave the required prediction for the decision making as it affects allocation of available running budget to each machine concerned. This developed model will be found applicable in any company, small, medium of large machine running cost management affects their day to day running of their machines.

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