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LIFE CYCLE COST ANALYSIS OF NBRRI DESIGNED AND FABRICATED INTERLOCKING BLOCK MAKING MACHINE

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Abstract

Most entrepreneurs calculate the cost of an asset based on initial cost only without consideration to cost relating to operation and maintenance throughout the lifetime of the asset. This traditional method of considering only the initial cost of an asset for decision making sometimes leads to incorrect conclusions. The ever-rising costs of operating and maintaining has given preference to the overall savings in the lifetime of an equipment that can be achieved by cost effective solutions in the design stage of the equipment. This paper therefore presents a life cycle cost, (LCC) analysis of a semi-automated interlocking block making Machine (SAIBM) designed and fabricated by the Nigerian Building and Road Research Institute, (NBRRI). The study was carried out by sourcing technical data from the Engineering Materials Research Department (EMRD), NBRRI mechanical workshop and data from the manufacturers of standard parts. These data included retail, operating, maintenance and disposal cost of the machine. LCC model was used alongside the Net Present Value (NPV) in estimating the true cost owning the machine assuming a 5 - year useful life. The LCC for the machine was estimated at an NPV of ₦ 12,888,566.73. with a proposed discount value of 4.5 % per annum. The findings from this study will give investors improved awareness of total cost of the equipment which will aid in planning, and effective decision making.

Keywords: life cycle cost, initial cost, standard parts, net present value, real interest rate

1. Introduction

In production of stabilized laterite Blocks or bricks, stabilization can be achieved by chemical stabilization (Deboucha & Hashim, 2010). In addition to chemical stabilizing, other stabilizing techniques are mechanical and physical stabilizing (Walker, 1995; Bilong *et al.*, 2008). The use of mechanical stabilization involves the use of mechanical energy using different types of rollers, rammers, vibration techniques and in some cases blasting. Ityokumbul *et al.*, (2016), Sunday *et al.*, 2019 considered extra loading on materials and equipment as a step require to cater additional situations. In planning and determining the replacement decision towards the equipment for compacting the soil, the use of life cycle cost analysis (LCCA) is important.

The Society of Automotive Engineers (SAE), (1999) defined life cycle cost (LCC) as the total cost of equipment from the cost of acquisition, down to operation, maintenance, conversion and or decommissioning. According to Wiktorsson, (2014), all supplier development cost, research and development, initiation, pre-study and projecting are included in the initial cost. In other words, LCC are costs estimates of an equipment or machinery from inception to disposal.

The main purpose of LCCA is to determine how to effectively reduce an assets ownership cost to achieve a financially viable project (Akinrata, 2016). Researchers according to (Bengtsson and Kurdve, 2016) suggest that the use of LCCA is a preferred option when making investment decisions. However, most industries do not consider the use of LCC when purchasing a machine. According to Higham *et al.*, (2016) a survey conducted in the UK revealed that 78% of industrial respondent rarely use LCC.

Ashworth and Hogg, (2007), stated that LCCA can be achieved by initially taking note of fundamental costs that will impact on the cost of ownership. This means LCC is data dependant and requires to be sourced accurately. Hence, Dhillon, (2010) asserted that the availability of reliable data is important to effectively perform LCCA. Important sources of information for life cycle cost analysis are i) manuals on cost for motors, centrifugal pumps, storage tanks (Corripio *et al.*, 1982a; Corripio *et al.*, 1982b), (; ii) costs of variety of processing equipment (Hall, 1982; Peters & Timmerhaus, 1980); and iii) unit price manuals (Dhillon, 2010).

LCCA, according to Kirk and Dell'Isola, (1995) is a management and decision-making tool. The objective is to choose the most cost-effective approach from series of alternatives available. Areas of application of LCCA includes, long range planning and budgeting, controlling an on-going project, deciding the replacement of an ageing equipment, construction sector, machineries and selecting among competitive bidders for a project (Deore & Ambre, 2019).

Past experience indicates that, often engineering system ownership cost always exceed initial costs. Various studies reveal that engineering systems ownership cost can vary from 10 to 100 times the original acquisition costs (Ryan, 1968). The term life cycle was first used in 1965 in a report entitled "Life Cycle Costing in Equipment Procurement" (U. S Logistics Management Institute, 1965). The report was prepared by the Logistics Management Institute, Washington D.C. This prompted the Department of Defence to publish a series of three guidelines for life cycle costing procurement. According to the Academy of Managed Care Pharmacy, AMCP (1976), the concept of LCC was formally adopted by the State of Florida and in 1975, a project entitled "Life Cycle Budgeting and Costing as an Aid in Decision Making" was initiated by the United States Department of Health, Education, and Welfare. In 1978, the U.S. Congress passed the National Energy Conservation Policy Act, which made it necessary for every new federal building to be life cycle cost effective (Moss, 1985). Since 1974, States within the United States such as New Mexico, Alaska, Maryland, North Carolina, and Texas have passed legislation that make life cycle cost analysis mandatory in the planning, design, and construction of all State buildings (Moss, 1985).

There is no documented report on the LCC of NBRRI interlocking block making machine as well as the brick making machine, therefore, this work is aimed at presenting a life cycle cost of one of the equipment (NBRRI Interlocking Block Making Machine) assuming a (5) year useful life. Fadeyi *et al.*, (2021). Showed the need for gorvrnment organization big corporation to make available access to resources for developing ideas. This document will aid investors willing to use the interlocking blocks made from laterite using the SAIBM machine to make cost effective decision for a profitable business.

2. Method

The machine understudied is the Semi-Automated Interlocking Block Making Machine, SAIBM (diesel generator driven), Fig. 1 shows the fabricated machine and the block. Technical data from the manufacturer and operators were used to determine the life cycle cost of the machine. The total useful life was assumed to be 5 years before obsolesce. The 5-year period of use is ±8 hours per day for 300 days in a year. Ogwu *et al.,* 2021) emphasized the need to get all the cost details embarking on a project. The technical information sourced for the machine were; manufacturers' suggested retail price (MSRP), operating costs, maintenance cost and disposal/decommissioning cost. These data were sourced from the Engineering Materials Research Department Workshop of NBRRI and technical specification for standard parts from the manufacturers.

Fig. 1: Semi-Automated Interlocking Block Making Machine, SAIBM and the block (Diesel Generator Driven)

Price of consumables were sourced from the market. LCC model applying equation 1 and engineering economic tools (Net Present Value) using equation 2 was used to determine the cost of ownership over a 5-year period.

$$LCC_e = PC_e + PV_{oe} + PV_{me} + D_e \qquad (1)$$

Where PC_e is procurement cost of the equipment

PV_{oe} is the present value of life cycle operating cost of the equipment

PV_{me} is the present of life cycle maintenance cost of the equipment

D_e is the equipment disposal cost

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Net present value PV_a of any activity *"a"* is given as

$$PV_a = C_a \left[\frac{1-(1+i)^{-k}}{i}\right] \quad (2)$$

Where PV_a is the present value of any activity

C_a is the estimated annual cost of any given activity

i is the discount rate

K is the equipment's expected useful life.

3. Results and Discussion

The NBRRI Stabilized earth bricks or blocks are produced by chemical stabilizing with 5% cement and mechanically stabilizing with a hydraulic press using electricity or powered by a diesel engine. The choice of diesel over gasoline is due to its reliability, durability and performance under load. The total LCC takes into account the procurement cost, the total operating and mainteinace costs and the disposal cost. The net present value (NPV) was used to discount all costs to the present value.

Table 1 shows the annual cost and 5 years' life cycle cost using the present value for owning a diesel powered SAIBM.

Table 1. Life Cycle Cost of Equipment for 5 Years at 4.5 % Discount Rate

S/N	*Description*	*Annual Cost (₦)*	*NPV (₦)*
1	MSRP	1, 050, 000.00	1, 050, 000.00
2	Operational Cost	2, 707, 808.00	11, 887, 214.15
3	Maintenance Cost	23, 600.00	103, 602.80
4	Residual Value		-152, 250.00
Total			12, 888, 566.73

From Table 1, the following components to make the total LCC is described as follows.

3.1 Technical Description and MSRP

The SAIBM machine Operated is not a fully automated machine. The machine uses a 6.3 KW diesel engine; which is air cooled and naturally aspirated, a single cylinder and 4 stroke engine with an engine speed of 3600rpm. Fuel consumption is 281 g/ kWh or 334 ml/kWh. It has a Gear pump of 230 bar, pump displacement of 5.89cm3/rev, pump speed 3000rpm and flow capacity 4.6 gpm. The MSRP is ₦ 1,050,000.00.

3.2 Operational Description per Annum

Cost of operating SAIBM Machine diesel driven per annum involves the following as sourced from the Engineering Materials Research Department of NBRRI and specifications and technical data from the manufacturers manual as stated by (Corripio *et al.*, 1982a; Corripio *et al.*, 1982b); Components of the operating cost are cost of diesel for running the engine, engine lubricating and hydraulic oil and daily wages for operators and laborers.

- Desel for production (D_0): the diesel consumption is given at 1.4 litres per hour from the technical data from manufacturers manual. This amounts to ₦ 772,800.00 per annum.
- Engine lubricating oil (L_o): The lubricating oil tank capacity is 1.65 liters. Using the recommended oil SAE10W-30 the estimated cost is ₦1,980.00 and frequency of renewal is 9.6 times per annum amounts to ₦19,008.00.
- First 50 hours of usage of hydraulic oil (H_0): change of hydraulic oil cost after first 50 hours of usage according to manufacturer's guide is put at ₦20,000.00. (Hydraulic oil tank capacity is 40 liters)
- Hydraulic oil (H_1): Cost is given at ₦20,000.00. and frequency of renewal is 4.8 times per annum amounts to ₦96,000.00
- Operators and labourers' daily wages (L_W): Cost of labor given that three (3) personnel operate the machine at ₦2,000.00 per day gives ₦1,800,000.00 per annum.

  (Data source: EMRD Mechanical Workshop, NBRRI).

Total operating cost, is given by;

$$T_{co} = L_o + H_0 + H_1 + L_W + D_0 \qquad (3)$$

3.3 Maintenance description/ cost

3.3.1 Diesel Engine

Desiel engine for powering the hydraulic system is maintained at the following schedules according to maintenance practice in the manufacturers' guide.

- Daily routine
- Every 100 hours
- Every 250 hours
- Every 500 hours
- Every 1500 hours (₦6,400.00 annually)
- Every 5000 hours (₦2,800.00 annually)

Total annual maintenance cost for the diesel engine is given by (C_E) = ₦9, 200.00 annually. (₦6,400.00 + ₦2,800.00).

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Maintenance guide is presented in the appendix as carried out by the mechanical workshop EMRD, NBRRI. All daily, 100 hours, 250 hours and 500 hours' maintenance are carried out by the operator of the machine, hence no cost is involved.

3.3.2 Hydraulic System

The hydraulic system is maintained at the following intervals as stipulated by the manufacturers.

- Routine / daily maintenance: Action carried out by operator.
- Every 500 hours: minor maintenance cost is estimated ₦14,400.00 annually.

Total maintenance cost is equal to Hydraulic system + diesel engine maintenance.

Maintenance activities for the diesel engine and hydraulic system are shown in the appendix

3.4 Residual value and NPV

The Residual Value is the value of the machine at the end of the useful life. Assuming a residual percentage of 10%, the residual value will be ₦152,250.00. The residual value in Table 1 has a negative value which means that there is an income by selling the machine as scrap after the equipment's useful life.

The NPV for owning the machine was calculated to be ₦ 12,888,566.73. using equation 2. Percentages of each of the items were 8.15%, 92.2%, 0.8% and 1.18% for MSRP, Operational Cost, Maintenance Cost and Residual Value respectively. Operation cost accounts for the greatest contribution representing 92.2% of the total LCC. Maintenance costs include cost of repairs and replacement of damaged or worn parts with schedules presented in the appendix. The total LCC is about 20 times over the initial cost which validates Ryan, (1968) that the engineering systems ownership cost can vary from 10 to 100 times the original acquisition costs. Hence when making investment decision the long-term expenditures should be considered more importantly to all associated initial costs.

4. Conclusion

Life cycle cost for diesel engine driven SAIBM was established by using the Net Present Value considering initial cost, operation and maintenance costs, replacement costs and non-annually recurring costs. The LCC was calculated to be ₦ 12,888,566.73, considering a useful life of 5 years. The method adopted can be used to establish LCCs for similar equipment with modifications of input data to identify ahead of time budgeting requirements and raise funds for same.

There is evidence of significant economic consideration in investing in SAIBM for the production of interlocking blocks for walling. The LCC cost benefit analysis carried out indicated that investing in the project (SAIBM) was viable considering the number of years used for the evaluation. The analysis is a booster for investiment confidence in the construction industry and creating a platform for value for money in the area of block production in the country.

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APPENDIX

GENERAL MAINTENANCE INSTRUCTIONS ON DIESEL ENGINE

DAILY-ROUTINE MAINTENANCE

a) Check Supply of Fuel Oil.

b) Check level and condition of lubricating oil. (Also, in gear box if fitted)

c) Clean Air cleaner in very dusty condition.

d) Drain moisture trap in exhaust pipe, if fitted.

e) Clean Rotary cooling air fan screen, if fitted.

EVERY 100 HOURS

a) Clean Air Cleaner under moderately dusty conditions.

b) Check for fuel and lubricating oil leaks-tighten nuts and fittings as necessary

c) Wipe engine and base plate clean.

d) Clean Cylinder, cylinder head and injector fining. Under every dusty conditions.

e) Check level of electrolyte in battery if electric starting is used. **

EVERY 250 HOURS

a) Drain Lubricating oil and refill with correct grade and

b) Check injector sprays and clean if necessary.

EVERY 500 HOURS

a) Decarbonizes, if engine shows loss of compression, or blow-by past the piston, but do not disturb otherwise.

b) Adjust valve tapped clearances.

c) Clean cooling fan, if necessary.

d) Wash engine down with paraffin or fuel oil

e) Renew lubricating oil filter element

f) Clean cylinder, cylinder head and injector fining under dusty conditions

EVERY 1500 HRS

a) Decarbonizes.

b) Clean inlet manifold and exhaust system.

c) Clean fins on cylinder head, injector and cylinder.

d) Examine fan blades and clean.

e) Check free working of Governor Linkage and lubricate

f) Drain and clean Fuel Tank

g) Replace fuel filter element. (Change gasket along)

h) Clean injector nozzles or replace by serviced ones.

j) Adjust injectors pressure setting.

k) Check fuel pump timing and balancing

l) Wash strainer in Fuel oil. Thoroughly dry it up and refit.

EVERY 5000 HOURS

a) Check Big End and Main bearing for tightness.

b) Inspect camshaft bearings and tappets.

c) Renew valve springs.