SMALL SCALE PRODUCTION OF AUTO-BATTERY IN NIGERIA: AN ENGINEERING ECONOMIC MODEL

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ABSTRACT

This work is aimed at determining the feasibility of manufacturing automobile batteries on a small scale level. It involves an economic evaluation directed at the typical 12V, 60Ah car battery. A process analysis was done with a view to determining the scalability of the processes. A review of relevant literature gives insights on the product structure and workings, material interactions, process requirements and the various manufacturing strategies and their respective benefits. The process is designed with a bias for outsourcing, a growing trend in the direction of specialization and agile product development. Thus, the process is designed for assembly as a parallel/flow line hybrid work system. Next, economic models are developed to assess costs, profit, revenue and optimal production volume. Also, breakeven and Payback Period models are developed for determining the viability of the venture. It was found that with 11 workers, the facility yields up to 1173 units of car battery per month. This requires an initial capital investment of ₦ 1,132,160. At an initial price of ₦ 5,500, the product is expected to generate monthly revenue of N6,450,830 at full running capacity. Thus, a profit margin of N 3,015,340 was obtained, amounting to 46.7% of total revenue. Breakeven occurs at a demand of 121 units, which is 10.3% of the monthly production capacity. This study shows the potentials and entrepreneurial opportunities of investing in the small scale manufacture of engineering products.

Keywords: Auto-battery, small scale manufacturing, economic models

NOTATIONS

- P : Unit price of the finished product.
- a : Price per unit of the product that is so high that it yields no demand.
- b : Amount by which demand increases for each unit decrease in price.
- D : Demand for the product.
- $\check{D}$: Demand at which maximum revenue is obtained.
- D^*: Optimal Demand (i.e. demand at which profit is maximized).
- D': Demand at which breakeven occurs.
- R_T: Total Revenue.
- y: Number of parts in battery
- k_i : Number of units of part i per battery. for which i= 1,2...y
- c_i : Cost per unit of part i.
- C_v : Total variable cost per month.
- c_v : Variable cost per unit of product.
- C_F: Total fixed cost per month.
- C_T: Total cost per month.
- l: total number categories of workers
- n_i : Number of workers in category i, for which i= 1, 2,......l
- s_i : Monthly salary of category i of workers.
- h: total number fixed cost components
- f_i : Monthly cost of fixed cost component i, for which i= 1, 2,......h
- v: Total number of facility under capital cost.
- m_i : Number of units of facility/equipment i.
- I_i : Cost per unit of facility/ equipment i. for which i= 1, 2,......v
- θ : Payback period.
- N : Study horizon for payback analysis.
- n : Study period under consideration
- P/F: Present worth given future worth.
- r : Minimum attractive rate of return.
- I : Initial capital investment.

1.0 INTRODUCTION

The much desired rapid economic development of Nigeria has been linked to the enhancement of the nation's small and medium scale manufacturing capabilities (Nwaigwe and Okoli 2004, Aderoba et al 2004). However there is a need to provide a pragmatic framework for the sustainable commercialization of made in Nigerian core engineering products. This involves the development of suitable business models, based on scaled down production systems of such engineering products, adapted to the Nigerian economic environment. Using the small scale manufacture of automobile battery as case study, this work seeks to develop such an engineering economic model.

The steady rise in the use of cars in Nigeria in recent time years has increased the demand for batteries by users and this has led to high cost of imported batteries and more disturbing is the importation of substandard batteries. Local automobile technicians have resorted to some ingenuous methods in refurbishing used batteries and other auto parts (Akinbinu, 2001); with such efforts offering much less reliability than the new ones. However, given the right enterprise structure, auto-battery is amenable to small scale production using locally available inputs. This work is targeted at determining the economic viability of producing car batteries at a small scale. The major source of concern is to determine how to manufacture batteries that meet regulatory standards and how to adapt the technology to its small scale manufacture in Nigeria economically. The work is focused on the 12-volt car battery.

2.0 PRODUCT AND PROCESS DESIGN

A number of factors such as similar existing products, Raw material Availability, Consumer Acceptance and Manufacturing Capability were considered in selecting the battery for manufacture. Consumer Acceptance was evaluated by interviews of sellers giving useful information regarding features which are most acceptable to the average consumer. This provides a basis for choosing the rating (60Ah) and other important features of the battery such as inclusion of refill holes.

A modern car battery has five basic parts: A resilient plastic container, Positive and negative internal plates made of lead, Plate separators made of porous synthetic material, a solution of sulphuric acid and water called Electrolyte, also known as battery acid and the Lead terminals. Car batteries can be classified into two broad classes namely Shallow Cycle and Deep Cycle (Bode 1977). The Shallow Cycle type is designed to deliver quick bursts of energy, usually to start an engine. They usually have a greater plate count in order to have a larger surface area that provides high amperage for short period of time. Once the engine is started, they are being continuously recharged. This type is the main concern of this work and is the one being used in the regular cars with fuel engines. The Deep Cycle type is designed to continuously provide power for long periods of time (for example in a golf cart). They can also be used to store energy from a photovoltaic array or a small wind turbine. They usually have thicker plates in order to have a greater capacity and survive a higher number of charge/discharge cycles.

2.1 Product Design Specification

Bearing in mind the above considerations, the product is designed to meet the following specifications: Type: - Shallow Cycle, Charge capacity: - 60Ah, Weight: - 9.5kg – 11.5kg, Quiescent voltage at full charge: - 12.6V, Energy to weight ratio: - 30Wh/kg Part Dimensions: - As specified in engineering drawings.

Process Design Consideration: Due to technology and material availability, the process is designed as an assembly line with a flow line structure. Intricate and highly sophisticated part processing are designed for out sourcing, while the product assembly is left as the core process of the manufacturing facility. This ensures minimum risk yet providing a unique product. The Assembly Flow Process Sheet (Table 2) provides a detailed view of the operations within the core of the assembly plant. It also shows the integration of other process components such as transportation, inspection, delays and storage. The associated times, for a single workman producing a unit, were obtained from a local battery recycling shop.

The product tree structure is shown in Fig. 2; this is an input to the bill of materials of Table 1 indicating whether a component is to be made in house or out sourced.

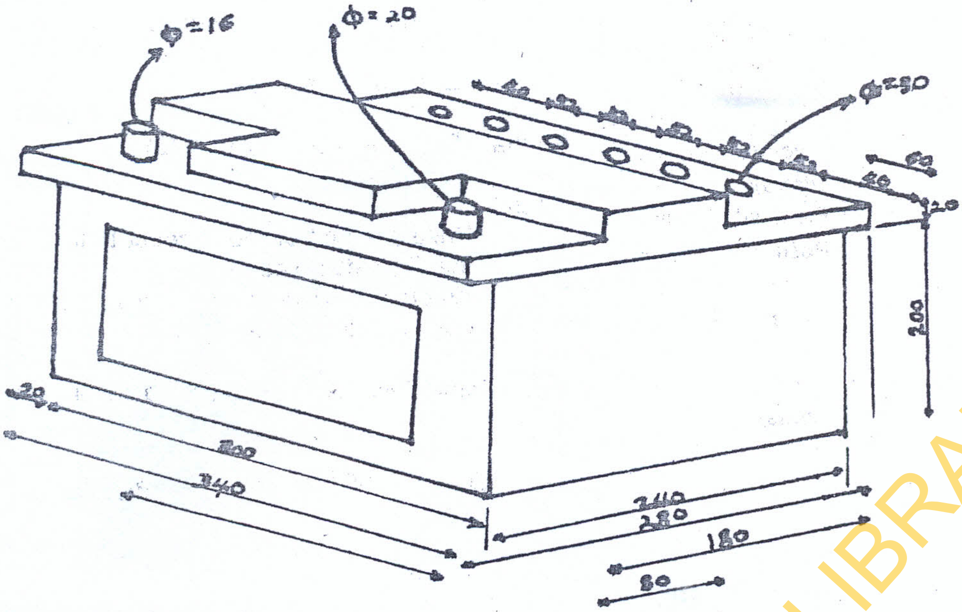


Fig. 1: Product after assembly

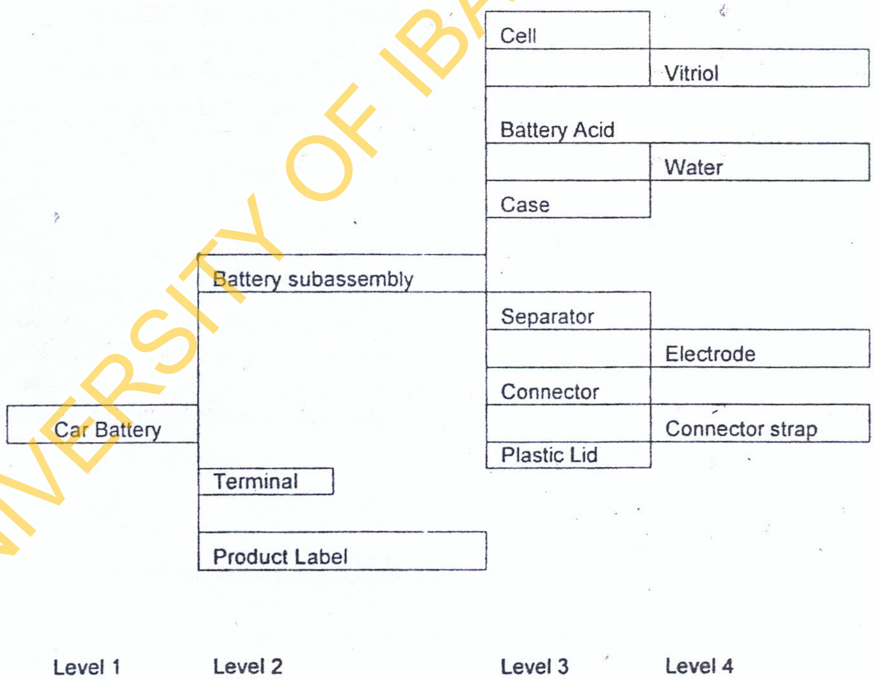


Fig. 2: Product Tree Structure

Table 1: Bill of Materials

Level	Description	Quantity	Unit	Make /Buy
3	Cell	6	Piece(s)	Buy
4	Acid (vitriol)	1.5	Litre(s)	Buy
3	Plastic case	1	Piece(s0	Buy
2	Terminals	2	Post(s)	Make
3	Separator	30	Piece(s)	Buy
2	Product Label	1	Piece(s)	Buy
4	Electrode	2	Stick(s)	Buy
3	Connector	10	Strap(s)	Make
4	Water	.3	Litre(s)	Make
3	Plastic lid		Piece(s)	Buy

Production Capacity

The production process, a flow line, consists of 14 distinct steps (Table 2). Workstations are formed by merging successive tasks that can be handled by an individual workman. Each of these is expected to be manned by at least one person. This encourages specialization, thus increasing the rate of production. Work study analysis indicates that with a production workforce of six people, the Manufacturing Lead Time MLT for a unit of product is 9 minutes; the time required at the workstation with the longest aggregated operation. With a standard 8 working hours per day and 22 working days per month, the Total Production Time TPT is given by TPT = 8hr/day x 60 min/hr x 22days/month = 10,560 minutes/month. Thus production Capacity/month =TPt/MLT = (10560min/month)/(9min per unit) = 1173 units per month = 53 units per day. If a higher production is desired, a parallel and identical process is created in order to double the output of the system.

Personnel Requirement

Besides the workmen involved with production, an office clerk, salesman and a manager are also required to handle administrative and sales distribution work.

3.0 ECONOMIC MODELS

Economic analysis is an important step in determining the feasibility of a product development effort. Appropriate costing templates and economic evaluation models are developed.

3.1 Model Development

Assuming a linear relationship between the price p and demand D of the product such that:

$$p = a - bD \text{ for } 0 \le D \le a, \text{ and } a > 0, b > 0 \quad \ldots(1)$$

So that $D = (a - p)/b \quad b \neq 0 \quad \ldots(2)$

where:

a : Price per unit of the product that is so high that it yields no demand.

b : Amount by which demand increases for each unit decrease in price.

Then Total Revenue R_T during a given period is given by:

$$R_T = P.D = aD - bD^2 \text{ for } 0 \le d \le a/b \text{ and } a > 0, b > 0 \quad \ldots(3)$$

Maximum revenue occurs at demand $\check{D}$ when $dTR/dD = a - 2bD = 0$ i.e. $\check{D} = a/2b$

$$\text{Maximum } R_T = a\check{D} - b\check{D}^2 = a^2/2b - a^2/4b = a^2/4b \quad \ldots(4)$$

Cost Analysis

At any demand D, total cost C_T per month is:

$$C_T = C_F + C_V \quad \ldots(5)$$

where C_F and C_V are the fixed and variable costs, respectively

$$\text{The variable cost, } C_V = D.c_V = D.\sum_{i=1}^{y} k_i c_i \quad \ldots(6)$$

where:

c_i : Cost per unit of part i.

c_v : Variable cost per unit of product.

k_i : Number of units of part i per battery. for which i= 1,2...y

where $c_v = \sum_{i=1}^{y} k_i c_i$ is total cost of components per unit.

The monthly fixed costs C_F are: 1) Fixed cost of labour and 2) Fixed cost due to overhead

$$C_F = \sum_{i=1}^{l} n_i s_i + \sum_{i=1}^{h} f_i \quad \ldots(7)$$

where:

n_i : Number of workers in category i , for which i = 1, 2,……*l*

s_i : Monthly salary of category i of workers.

f_i : Monthly cost of fixed cost component i, for which i= 1, 2,……*h*

$$\text{Then } C_T = D.(\sum_{i=1}^{v} k_i c_i) + (\sum_{i=1}^{l} n_i s_i + \sum_{i=1}^{h} f_i) \quad ...(8)$$

Capital Investment

The capital cost **Cc** spent on machines, electrical fittings, etc, regarded as a sunken and finds its use in the Payback Period analysis model.

$$Cc = \sum_{i=1}^{v} m_i I_i \quad ...(9)$$

where:

m_i : Number of units of facility/equipment i.

I_i : Cost per unit of facility/ equipment i. for which i= 1, 2,……*v*

Profit

Profit(loss) = total revenue – total costs

$$= (aD - bD^2) - (C_F + c_v D) = -bD^2 + (a - c_v)D - C_F$$

for $0 \le D \le a/b$ and $a > 0$, $b > 0$

$$= -bD^2 + (a - \sum_{i=1}^{v} k_i c_i)D - (\sum_{i=1}^{l} n_i s_i + \sum_{i=1}^{h} f_i) \quad ...(10)$$

Optimal Demand

The optimal value of demand D* that maximizes profit occurs when:

$$d(\text{profit})/dD = a - c_v - 2bD = 0$$

$$D^* = (a - c_v)/2b = (a - \sum_{i=1}^{v} k_i c_i)/2b \quad ...(11)$$

Breakeven Point

At breakeven point:

Total revenue = Total cost. i.e.

$$aD - bD^2 = C_F + c_v D - bD^2 + (a - c_v)D - C_F = 0 \quad ...(12)$$

Solving Eqn. (12) we obtain:

$$D' = -(a - c_v) \pm [(a - c_v)^2 - 4(-b)(-C_F)]^{1/2}\}/2(-b) \quad ...(13)$$

where the values of D' correspond to the demand at breakeven point.

Typically, the smaller of the two D's is of greater reckoning and thus:

$$D' = -(a - \sum_{i=1}^{v} k_i c_i) \pm [(a - \sum_{i=1}^{v} k_i c_i)^2 - 4(-b)-(\sum_{i=1}^{l} n_i s_i + \sum_{i=1}^{h} f_i)]^{1/2}\}/2(-b) \quad ...(14)$$

Discounted Payback Period

In determining the discounted payback period the initial capital investment Cc is used. The discounted payback serves as a measure of business risk and gives the time that the enterprise becomes truly profit-making. Assuming an infinite horizon N and that all cash flows occurring after the payout period are not put into consideration:

Payback period, θ, (θ ≤ N), is given by:

$$\sum_{n=1}^{\theta} (R_T - C_T)_n (P/F, r\%, n) - Cc \ge 0 \quad ...(15)$$

where:

R_T and C_T refer to the total revenue and total cost at the end of period n.

r is the minimum attractive rate of return.

The expression ($R_T - C_T$) is equal to that for profit in equation 10 . Thus payback period, θ, is specifically given by:

$$\sum_{i=1}^{\theta} [-bD^2 + (a - \sum_{i=1}^{v} k_i c_i)D - (\sum_{i=1}^{l} n_i s_i + \sum_{i=1}^{h} f_i)]_n (P/F, r\%, n) - \sum_{i=1}^{v} m_i I_i \ge 0 \quad ...(16)$$

3.2 Model Application

Price-Demand Relationship

A market survey was carried out to obtain prices of popular brands of 60Ah batteries. This is shown in Table 3.

Table 3: Prevailing prices of existing brands

Brand Name	Prevailing Price (₦)
S.F.B	5000
Interland	5500
Forgo	5000
Vega	6500

The mean price of these brands, P = ₦ 5,500 is recommended as the initial price for the product, since a price as high as (or higher than) costliest brand may meet consumers resistance because it is a new brand that has no reputation. Conversely, a price as low as (or lower than) the cheapest brand may suggests inferiority and put off consumers.

With a demand D corresponding to factory capacity of 1173/month and ₦ 6,500, the price of the costliest reputable brands, as the highest reasonable price that can be fixed for the product. Then for eqn. 1,i we obtain:

5500 = 6500 – b(1173) => b = 0.853
P = 6500 – 0.853D

Revenue and Cost Analysis

At full capacity,

Total monthly revenue R_T = 6500 x 1173 – 0.853(1173)^2 = ₦ 6,450,830; equation 2

The total variable cost C_V = 2530 x 1173 = ₦ 2,967,690 ; equation 6

The total fixed cost due to labour and overhead C_F = ₦ 467,800 equation 7

Total production cost, C_T = 467800 + 2967690= ₦ 3,435,490; equation 8

Profit (or Loss)

For the profit (loss) evaluation equation x yields

Profit (loss) = - 0.853(1173)^2 + (6500 – 2530)(1173) – (450000 + 17800) = ₦ 3,015,340

Optimal Demand

The value of demand that brings maximum profit according to equation (11) is given by:

D* = (6500 – 2530)/2(0.853) = 2327 units

This value is approximately twice the production capacity of 1173. It suggests that if the actual demand is close to this, it would be advisable to replicate the production process to maximize profit, provided resources allow for it.

Breakeven Point

Going by equation (12), breakeven occurs at demand value D'

D' = {-(6500 – 2530) ± [(6500 – 2530)^2 - 4(-0.853)(-(450000 + 17800))]$^{1/2}$}/2(-0.853)
= 121 or 4533 (the smaller being of interest)

Hence breakeven occurs with a demand of 121 units.

Discounted Payback Period

Payback period θ is given by equation (13i). Assuming a Minimum Attractive Rate of Return (MARR) of 1% per month, at the end of the first month, the discounted payback is:

[- 0.853(1173)^2 + (6500 – 2530)(1173) - (450000 + 17800)]$_1$(P/F, 1, 1) – 1132160 = ₦ 1,853,330 > 0

This value is significantly greater than 0, which indicates that the business venture will totally recover all expenses within its first month of operation with an excess of the indicated amount. Also, the risk of failure is extremely low at 1% MARR. Using a much higher MARR i.e. 25% to establish or refute this speculation, we obtain the discounted payback as:

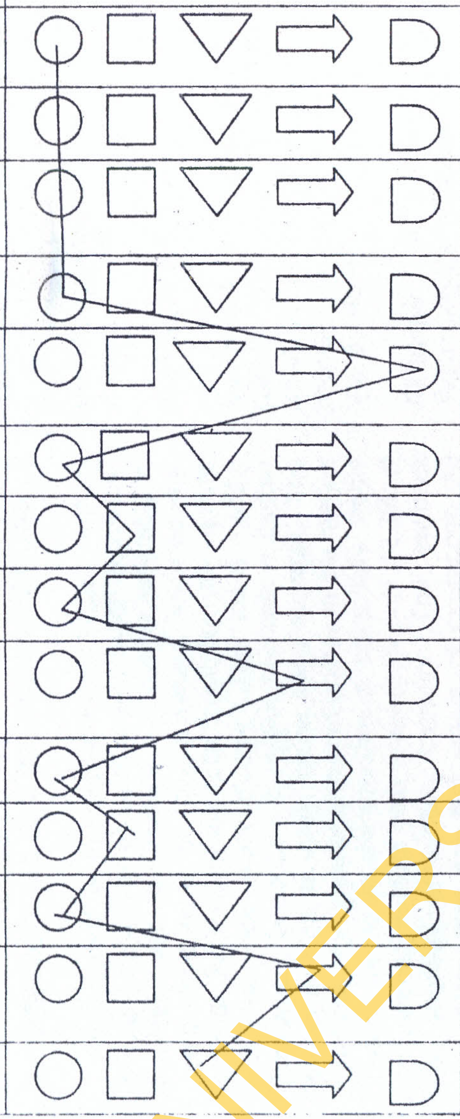
[- 0.853(1173)^2 + [6500 – (2530 + (1/1173)450000)] 1173 – 17800] x
(P/F, 25, 1) – 1132160
= ₦ 1,280,120 > 0

The resultant difference between the two is insignificant and we thus conclude that the venture is guaranteed to completely recover all expenses within the first month of its operation. More so, an excess of ₦ 1,280,120 will result (assuming all units produced within that month are completely sold in the same month).

Table 2: Assembly Flow Process She[et] ○ Operat[ion] □ Inspectio[n] ▽ Sto[rag]e D Delay ⇨ Transportation

Name of Part: Car Battery

No.	Symbol	Description	Distance Moved (metres)	Operation	Transportation	Delay	Inspection
				Time in Minutes			
1		Form plate sets.	-	2	-	-	-
2		Cast on straps.	-	10	-	-	-
3		Place elements into case & fit connectors.	-	10	-	-	-
4		Seal cover unto case.	-	12	-	-	-
5		Heat lead & collect from furnace.	-	-	-	3	-
6		Cast terminals on .	-	5	-	-	-
7		Test for leaks.	-	-	-	-	2
8		Fill battery with acid.	-	6	-	-	-
9		Move battery to charging point.	10	-	1	-	-
10		Critically charge battery	-	300	-	-	-
11		Carry out electrical and mechanical tests.	-	-	-	-	4
12		Clean and label battery.	-	3	-	-	-
13		Move battery to store.	5	-	3	-	-
14		Battery - in - store.	-	-	-	-	-



4.0 CONCLUSIONS AND RECOMMENDATIONS

The product is the typical 60Ah battery with a simple design. The process is very much adaptable to small scale manufacture. It is mainly assembly in design and most of the operations involved are manual. In terms of financial feasibility, the venture offers a wide profit margin. The initial capital investment is about 1.2 million but with expected profits as high as three million naira monthly. The relatively high price of imported brands in the market makes the local manufacture a potentially viable engineering venture with breakeven only 10.3% of the monthly production capacity. The payback period is within the first month of operations. All investments are recovered in excess of over one million naira.

Meanwhile similar studies are recommended for other products that are mostly imported at the moment. These could bring to light the opportunities and the prospects of investing in the small scale manufacture of engineering products.

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