Effect of Capital and Operating Cost on the Aggregate Production in Some Selected Quarries in North-Central Nigeria

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Authors’ contributions

This work was carried out in collaboration between all authors. Author PAA drafted the questionnaires, performed the statistical analysis and drafted the first manuscript. Author MAG managed the literature searches and analyses of the study. Author ZOO designed the study. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The study examines the effect of capital cost and operating cost on some selected quarries within North-Central Nigeria.

Study Design: Survey design was used in designing the questionnaire used for collecting data from the selected quarries.

Study Area and Methodology: Twenty-four quarries were selected in North-Central Nigeria for this study. Sixteen of these quarries were for commercial purposes while eight were for construction purposes. A total number of one hundred and fifty-five questionnaires were randomly distributed to the workers and managements of the various quarries to collect data on the quantity of granite rock blasted per month, cost of drilling accessories used, cost of explosives used, cost of maintenance of plant/equipment and cost of manpower. Net Present Value (NPV) and Internal Rate of Return (IRR) were the two economic evaluation data analyses used for the study because they rely on the time value of money.

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**Results:** The result shows that Majok quarry, Cafon quarry, Rock bridge quarry, Academ quarry, Trans Engineering and Sinac granite quarry are not doing well as their internal rate of returns falls short of the annual internal rate of returns of 20%. This indicates that the companies could not break even as they failed to cover the average operating cost.

**Conclusion:** The study noted that it is not only huge capital cost that determine the production cost of aggregates, rather, such measures as the size of the jaw of the crushing plant, appropriate spacing and burden drilling plan are very important to guide against the extra operating cost of secondary blasting.

**Keywords:** Capital cost; operating cost; net present value; internal rate of returns.

1. **INTRODUCTION**

Quarries are classified as surface mining, which involves some basic cycle’s operations such as excavation, drilling and blasting, loading, haulages from the quarry face to the crushing plant, crushing and maintenance of the machinery and equipment [1]. All these determine the success or failure of quarry operations. Drilling and blasting are the most important factors in quarry operations. Blasting is the principal method of rock breakage in mining and construction projects throughout the world. This may probably be due to its distinct advantages like economy, efficiency, convenience and ability to break the hardest of rocks [2]. With these two factors, a reasonable estimate can be made for the number of drills required and the cost implications [3]. If these operations are not successful, then the viability of the quarry becomes jeopardized. Also, Howard [4] noted that the development of production, utilization is very important in quarry operation which involves an overall job efficiency of 60%, a mechanical availability of 80% and an annual outage factor of 95%, yielding production utilization 46%. Peter [5] revealed that low overall job efficiency can occur when moving the drill from hole to hole and the low mechanical availability occurs when blast hole drill encounter rough usage. He therefore concluded that effort should be made to avoid secondary blasting and better primary blasting should be ensured since it increases the overall production of one ton of rock produced.

Opafunso [6] stated quarry project is a capital intensive investment with many uncertainties as a result of geologic condition, reserve estimations, severe problems in forecasting aggregate prices and production costs while Mainoma [7] noted that the overall economic viability of any quarry from a lender’s point of view is mainly test through cash flow analysis. David [8] enumerated four important principles of an economic model for investment decisions which are; the incremental principle, the principle of time perspective, the opportunity cost principle and the discounting principle. Tobi [8] described these principles as the frameworks of economic analysis which interrelate the areas of quarrying, technology for drilling and blasting, the annual turnover, the capital investment required, the estimated operating costs, and the profitability criteria for the final investment decision. The evaluation of profitability of investment is the final analysis, which is measured by the difference between the summation of the present value of the expected proceeds over future years and the initial outlay invested today [9].

The objective of production schedule is to maximize the net present value and return on investment that obtained from the drilling and blasting, crushing and sale of aggregates from quarrying activities. Tijani [10] noted that an optimum production schedule in quarrying activities depends on two parameters. The first parameters are the stripping ratio associated with recovering the ore, the grade of that ore, and the physical location of that ore in respect to availability through time while the second parameters consist of costs associated with starting and maintaining the whole operation. The high risk and large capital expenditures, which are characteristics of the quarrying industry have made financial analysis as one of the crucial elements in the resource development process. In view of these facts, this study carried out comprehensive analyses of fixed and variable costs in some selected quarries with the aim of finding ways of reducing some of these costs and sustaining the profit maximization.

2. **METHODOLOGY**

2.1 **Description of the Study Area**

Twenty four quarries were selected in North-Central Nigeria for this study as shown in Table 1.
Table 1. Names and locations of quarries sites

| S/N | Quarry owner             | State | LGA          |
|-----|--------------------------|-------|-------------|
| 1   | Setraco Nig. Ltd         | FCT   | Bwari       |
| 2   | Crushed Rock Industries ltd. | FCT | Bwari       |
| 3   | Exsamines Nig. Ltd       | FCT   | Bwari       |
| 4   | Majok Nig. Ltd           | FCT   | Bwari       |
| 5   | Trans & Eng. Nig. Ltd.   | FCT   | Bwari       |
| 6   | ENL Company Ltd.         | FCT   | Bwari       |
| 7   | SCC Nig. Ltd             | FCT   | Bwari       |
| 8   | Gilmo Engineering Nig. Ltd. | FCT | AMAC       |
| 9   | Alhaji Abdullah Gbojega   | Niger  | Chanchanga  |
| 10  | Gold International Nig. Ltd | Niger | Chanchanga  |
| 11  | Bulletine Construction Co. Ltd | Kogi  | Lokoja     |
| 12  | Sinac Granite Product Intl. ltd | Kogi | Ajaokuta   |
| 13  | Julius Berger Nig. Plc   | Kogi  | Ajaokuta   |
| 14  | Lubbox Limited           | Kwara | Asa        |
| 15  | Confidence Const. Co. Ltd. | Kwara | Asa        |
| 16  | Aron Stones Limited      | Kwara | Asa        |
| 17  | Sarki & Adisa Co. Ltd    | Kwara | Ilorin West|
| 18  | Cafon Ventures Nig. Ltd. | Kwara | Ilorin West|
| 19  | Mukan & Sons Nig. Ltd.   | Plateau | Bassa   |
| 20  | P.W. Nigeria Ltd         | Benue | Katsina Ala|
| 21  | Academ Const. Co Ltd     | Benue | Katsina Ala|
| 22  | Just & Lawson Company Ltd. | Nasarawa | Nasarawa |
| 23  | Nasarawa Minerals Dev. Co. Ltd. | Nasarawa | Nas/Eggon |
| 24  | Rock Brigde Const. Ltd.  | Nasarawa | Nas/Eggon |

Sixteen of these quarries were for commercial purposes while eight were for construction purposes. Ten of the quarries were owned by the foreigners, while fourteen were owned by indigenous firm. Throughout the period of data collection for this study, five of the quarries were not in operation while ten were on skeletal operations and ten were in continuous production.

Table 2. Average selling price for granite aggregates products

| S/N | Sizes / Aggregates     | Price / Tonne (N) |
|-----|------------------------|------------------|
| 1   | 0 - 5 mm (Dust)        | 1,100            |
| 2   | 5 - 10 mm (3/8")      | 2,250            |
| 3   | 10 - 15 mm (1/2")     | 2,750            |
| 4   | 15 - 22 mm (3/4")     | 2,250            |
| 5   | 22 - 35 mm (1")       | 2,200            |
| 6   | Crushed stone base     | 1,650            |
| 7   | Hard core              | 1,650            |

2.2 Data Collection and Analysis

A total number of one hundred and fifty-five questionnaires were randomly distributed to the workers and managements of the various quarries to collect data on the quantity of granite rock blasted per month, cost of drilling accessories used, cost of explosives used, cost of maintenance of plant/equipment and cost of manpower. The data collected was used to determine the total variable cost and cost to produce a tonne of granite aggregate. Average selling price per tonne of granite aggregate was also collected as shown in Table 2.

Net Present Value (NPV) and Internal Rate of Returns (IRR) were the two economic evaluation data analyses used for the study because they rely on the time value of money. NPV and IRR were used to calculate the cash flows annuity for three years at 20% annual rate by using Equations (1) and (2). Also, the cost of producing one tonne of granite aggregate was calculated by using Equation (3).

\[
NPV = R \times \frac{1 - (1 + i)^{-n}}{i} - \text{Initial Investment} \quad (1)
\]
Where “NPV” is Net present value, “i” is rate of lending in % and “n” is the number of years

$$IRR = \frac{(LR + (+NPV))(HR - LR)}{PV} + PV^2$$ (2)

Where, “IRR” is the internal rate of return, LR is Lower rate, HR is higher rate and +NPV is Positive NPV

$$CPTA = \frac{TVC}{NTP}$$ (3)

Where, CPTA is the cost per tonne of granite aggregate, TVC is the total variable cost and NTP is the number of tonne of granite aggregate produced.

3. RESULTS AND DISCUSSION

3.1 Results

The following results were generated from the data analyses: total variable cost, the cost to produce a tonne of granite aggregate and cash inflows for the period of three years as shown in Tables 3, 4 and 5.

3.2 Discussion

Fig. 1 shows the performance of the selected quarries. It was observed that Majok quarry, Cafon quarry, Rock bridge quarry, Academ quarry, Trans Engineering and Sinac granite quarry are not doing well as their internal rate of returns falls short of the annual internal rate of returns of 20%. This indicates that the companies could not break even as they failed to cover the average operating cost. It is not advisable for the firms to close down, even when the average variable cost could be covered at a loss would be minimized if the companies continue production. This is because if the companies close down, then, the business would still incur the capital cost which is unavoidable whether production continues or not.

Meanwhile, if the price falls and the companies could no longer cover its variable cost, then it is advisable for the companies to close down. Otherwise, the companies will not only lose its capital cost but also part of its operating cost.

Figs. 2, 3 and 4 show the comparative analyses of total capital cost, total operating cost and total cost of producing one tonne of granite aggregate for each of the quarries. It was observed from the figures that Julius Berger quarry has the highest capital cost of N874,000,000.00 and operating costs of N24,573,344.00 and produces one ton of aggregate at an average cost of N386.00 while Rock Bridge with the lowest capital cost of N55,000,000.00 and operating costs of N29,760,000.00 produces one ton of aggregate at a whopping rate of N620.00 annually. Majok quarry produces one tonnage of aggregate at the highest operating cost of N900.00 with a capital cost of N85,000,000.00 while P.W. quarry with one of the highest capital cost of N755,000,000.00 produces one ton of aggregate at the lowest rate of N204.00. This shows that quarry with high operating costs will find it difficult to break even. This is the reason why Majok quarry with -16% of IRR cannot breakeven while Julius Berger and Gilmo quarries with 87% and 74% of IRR are doing well as a result of their very huge capital cost.

![Fig. 1. Graph of comparative performance between successful and unsuccessful quarries](image-url)
| S/N | Quarries                  | Quantity of rock produced (tonne) | Royalty (N25/ton) (N) | Cost of drilling accessories (N) | Cost of explosive (N) | Cost of equipment maintenance (N) | Cost of man power (N) | Total variable cost (N) |
|-----|---------------------------|-----------------------------------|-----------------------|----------------------------------|----------------------|----------------------------------|----------------------|------------------------|
| 1   | Setraco Nig. Ltd.         | 60,000                            | 1,500,000             | 1,270,316                        | 15,385,850.00        | 6,843,834.00                     | 1,460,000.00         | 26,460,000.00          |
| 2   | Crushed Rock Industries Ltd. | 48,912.50                        | 1,222,813             | 650,320                          | 2,771,161.04         | 10,896,400.00                    | 2,366,172.71         | 15,540,693.54          |
| 3   | Examine Nig. Ltd.         | 21,008                            | 525,200               | 392,906                          | 2,324,275.69         | 9,506,855.49                     | 1,565,824.10         | 14,315,061.28          |
| 4   | Majok Nig. Ltd.           | 23,333                            | 583,325               | 802,125                          | 10,232,150.00        | 6,900,000.00                     | 3,065,725.00         | 21,583,325.00          |
| 5   | Trans Eng. Nig. Ltd.      | 34,043                            | 851,075               | 464,882                          | 9,607,200.00         | 5,000,000.00                     | 1,268,735.00         | 17,191,892.00          |
| 6   | ENL Company Ltd.          | 81,000                            | 2,025,000             | 4,383,190                        | 12,774,150.00        | 7,331,960.00                     | 1,782,660.00         | 28,296,960.00          |
| 7   | SCC Nig. Ltd.             | 47,236                            | 1,180,900             | 438,680                          | 2,374,381.33         | 12,969,016.63                    | 1,842,146.00         | 18,805,123.96          |
| 8   | Gilmo Engineering Nig. Ltd. | 50,375                           | 1,259,375             | 398,530                          | 2,463,280.00         | 11,800,110.86                    | 1,200,170.00         | 17,121,465.86          |
| 9   | Bulletine Construction Co. Ltd. | 12,480                           | 312,000               | 280,184                          | 2,029,336.93         | 3,566,018.97                     | 828,965.70           | 7,016,505.60           |
| 10  | Sinac Granite Production Intl. Ltd. | 35,000                           | 875,000               | 995,740                          | 7,009,820.00         | 6,840,560.00                     | 1,635,000.00         | 17,356,120.00          |
| 11  | Julius Berger Nig. Plc    | 63,601.20                         | 1,590,030             | 810,368                          | 8,327,518.00         | 14,369,800.70                    | 1,065,654.54         | 26,163,717.24          |
| 12  | Cafon Ventures Nig. Ltd.  | 35,200                            | 880,000               | 773,118                          | 7,016,100.00         | 15,460,782.00                    | 3,150,000.00         | 27,280,000.00          |
| 13  | Mukan & Sons Nig. Ltd.    | 45,000                            | 1,125,000             | 1,170,084                        | 7,232,096.00         | 6,875,000.00                     | 2,092,821.00         | 11,620,001.00          |
| 14  | P.W. Nigeria Ltd.         | 80,229                            | 2,005,725             | 780,668                          | 6,862,400.00         | 6,657,749.04                     | 2,040,000.00         | 18,546,524.04          |
| 15  | Academ Const. Co Ltd.     | 55,000                            | 1,375,000             | 780,668                          | 7,009,820.00         | 16,896,400.00                    | 1,625,000.00         | 27,686,888.00          |
| 16  | Rock Brigde Const. Ltd.   | 48,000                            | 1,200,000             | 1,398,466                        | 12,466,010.00        | 11,120,000.00                    | 4,775,524.00         | 30,960,000.00          |
Table 4. Cost of producing a tonne of granite aggregate

| S/N | Quarries                          | Cost of granite aggregate/ton (N) | Total capital cost (N) | Total operating cost (N) |
|-----|----------------------------------|-----------------------------------|------------------------|--------------------------|
| 1   | Setraco Nig. Ltd                | 416                               | 610,000,000            | 25,000,000               |
| 2   | Crushed Rock Industries Ltd.    | 341                               | 660,000,000            | 16,340,810               |
| 3   | Examines Nig. Ltd               | 656                               | 320,000,000            | 13,789,865               |
| 4   | Majok Nig. Ltd                  | 900                               | 85,000,000             | 21,000,000               |
| 5   | Trans Eng. Nig. Ltd             | 480                               | 250,000,000            | 16,340,817               |
| 6   | ENL Company Ltd                 | 320                               | 310,000,000            | 25,920,000               |
| 7   | SCC Nig. Ltd                    | 373                               | 401,000,000            | 17,624,636               |
| 8   | Gilmo Engineering Nig. Ltd      | 319                               | 523,610,000            | 16,042,090               |
| 9   | Bulletin Construction Co. Ltd.  | 537                               | 200,000,000            | 6,704,551                |
| 10  | Sinac Granite Product Intl. Ltd | 510                               | 75,000,000             | 17,850,000               |
| 11  | Julius Berger Nig. Plc          | 386                               | 874,000,000            | 24,573,344               |
| 12  | Cafon Ventures Nig. Ltd         | 750                               | 110,000,000            | 26,400,000               |
| 13  | Mukan & Sons Nig. Ltd           | 386                               | 122,000,000            | 17,370,000               |
| 14  | P.W. Nigeria Ltd                | 204                               | 755,000,000            | 16,340,817               |
| 15  | Academ Const. Co Ltd            | 473                               | 401,000,000            | 26,311,888               |
| 16  | Rock Bridge Const. Ltd          | 620                               | 55,000,000             | 29,760,000               |

Fig. 2. Comparative of total capital cost of the quarries

Fig. 3. Comparative analyses of total operating cost of the quarries
Table 5. Cash Inflow for the period of three year at 20% annual rate

| S/N | Name of quarries               | Initial investment (N) | Year 1 (N)   | Year 2 (N)   | Year 3 (N)   | IRR (%) | NPV (N)       |
|-----|--------------------------------|------------------------|--------------|--------------|--------------|----------|---------------|
| 1   | Setraco Nig. Ltd               | -610,000,000           | 350,000,000  | 350,000,000  | 350,000,000  | 33       | 737,268,518.52|
| 2   | Crushed Rock Ind. Ltd          | -660,000,000           | 890,000,000  | 890,000,000  | 890,000,000  | 123      | 1,874,768,518.52|
| 3   | Examine Nig. Ltd.              | -320,000,000           | 255,000,000  | 255,000,000  | 255,000,000  | 60       | 537,152,777.78|
| 4   | Majok Nig. Ltd.                | -85,000,000            | 20,000,000   | 20,000,000   | 20,000,000   | -16      | 42,129,629.63 |
| 5   | Trans Eng. Nig. Ltd.           | -250,000,000           | 110,000,000  | 110,000,000  | 110,000,000  | 15       | 231,712,962.96|
| 6   | ENL Company Ltd.               | -310,000,000           | 270,000,000  | 270,000,000  | 270,000,000  | 69       | 568,750,000.00|
| 7   | SCC Nig. Ltd.                  | -401,000,000           | 450,000,000  | 450,000,000  | 450,000,000  | 98       | 947,916,666.67|
| 8   | Gilmo Engineering Nig. Ltd.    | -523,610,000           | 480,000,000  | 480,000,000  | 480,000,000  | 74       | 1,011,111,111.11|
| 9   | Bulletine Const. Co. Ltd.      | -200,000,000           | 255,000,000  | 255,000,000  | 255,000,000  | 115      | 537,152,777.78|
| 10  | Sinac Granite Prod. Intl. Ltd. | -75,000,000            | 35,000,000   | 35,000,000   | 35,000,000   | 19       | 73,726,851.85 |
| 11  | Julius Berger Nig. Plc         | -874,000,000           | 900,000,000  | 900,000,000  | 900,000,000  | 87       | 1,895,833,333.33|
| 12  | Cafon Ventures Nig. Ltd        | -110,000,000           | 28,000,000   | 28,000,000   | 28,000,000   | -12      | 58,981,481.48 |
| 13  | Mukan & Sons Nig. Ltd.         | -122,000,000           | 85,000,000   | 85,000,000   | 85,000,000   | 48       | 179,050,925.93|
| 14  | P.W. Nigeria Ltd.              | -755,000,000           | 600,000,000  | 600,000,000  | 600,000,000  | 60       | 1,263,888,888.89|
| 15  | Academ Const. Co Ltd.          | -410,000,000           | 150,000,000  | 150,000,000  | 150,000,000  | 6        | 315,972,222.22|
| 16  | Rock Brigde Const. Ltd.        | -55,000,000            | 20,000,000   | 20,000,000   | 20,000,000   | 4        | 42,129,629.63 |
Fig. 4. Comparative analyses of total cost of producing one tonne of granite aggregate

4. CONCLUSION

The study noted that it is not only huge capital cost that determine the production cost of aggregates, rather, variable costs such as explosives and explosive accessories cost, cost of drilling and cost of equipment maintenance which are equally determined by the blast design (size of the jaw of the crushing plant, appropriate spacing and burden drilling) are very important to guide against extra operating cost of secondary blasting. The study, therefore recommended that all the unsuccessful quarries should invest more and increase their capital cost so that the operating costs will be drastically reduced. Technical procedures (such as holes diameter, water conditions, burden, spacing, bench height, rock structure, desired shape of the muck pile, size and type of handling and crushing equipment and of course, the type of explosives used and the kind of ignition) which dictate by the condition of the deposit should be strictly followed before setting up quarry operation in order to guide against the high rate of aggregate production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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