



Analysis of the Short Fall in Production Target and Specific Cost of Unit Operations in National Iron Ore Mining Company NIOMCO, Itakpe.

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A B S T R A C T

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This paper practically analyzed comprehensively the problems encountered in the production of run-of-mine (ROM) ore in National Iron Ore Mining Company (NIOMCO), Itakpe. This work x-rayed the possible reasons for the shortfall in production target of one million ton per annum set by the management in 1992 despite the huge financial commitment on staff welfare, incentives and bonuses. Against this back drop, a research was conducted to assess the productivity of the equipment fleet of each unit operation with a view to finding out whether the equipment fleet in any of the unit operations was creating the bottle-neck in the production system. The methodology of this research was based on the assessment of the productivity of the equipment fleet of each unit operation, notably drilling and blasting, mucking and haulage operations with a view to finding out whether the equipment fleet in any of the unit operations was creating the bottle-neck in the production value chain. The equipment involved was three rock drills (1 ROC 608 and 2 ROC 404) for drilling operation; and five mucking and haulage facilities respectively. These include 2 mucking equipment (950C) and 3 haulage facilities (R35). In the final analysis, it was discovered that even though the equipment fleet in drilling and blasting unit and in the loading operations unit could produce well above one million tons of run-of-mine ore per annum, the equipment fleet in the haulage unit were grossly inadequate. This explains why the one million tons target set in 1992 was not achieved. The graphic details of the production level of the fleets were, drilling equipment fleet produced approximately 1.84 million tons; loading equipment produced approximately 5.52 million tons; while the haulage produced about 0.6 million tons. The specific cost of unit operations for the production of a ton of run-of-mine ore was found to be N60.

1. Introduction

Itakpe Iron deposit in Nigeria is of magnetite-hematite mineralization with average iron content of 36%. It is a hilly deposit with an estimated geological reserve of two hundred million tons of iron ore. Itakpe hill is about 500 km North East of Lagos and about 200 km South of Abuja, the Federal Capital of Nigeria, 50 km South of Lokoja, the Kogi State Capital; with its geographical coordinates in latitude 70 36' 20" North and in longitude 60 18' 35" East, has been recognized as an important source of Iron Ore since 1905. The National Iron Ore Mining Company (NIOMCO) was designed to produce and supply 100% and about 40% of the iron ore requirements of Ajaokuta and Delta Steel Plants, respectively. These represents as follows: Ajaokuta Steel Plant: 2,135 million tones of iron ore concentrate with 64% Fe; Delta Steel Plant: 0.55 million tones of iron ore concentrate with 68% Fe. The production rate of a mine determines the sizes of the machinery, plants, personnel, ancillary facilities and infrastructure (Hartman and Howard, 1987). Nigeria is blessed with abundant reserves of solid mineral, which are

recovered through surface or underground mining methods. However, our ability to optimally tap and utilize these solid minerals will depend on the application of appropriate policy and technology of mineral exploitation (Nwosu, 1994). An ore can be described as an accumulation of mineral in a sufficient quantity as to be capable of economic extraction (Wills, 2006). Aso and Ajayi (1999) opined that the wealth of any nation depends on its mineral resources and how these could be explored and exploited to improve the nation's economy.

Iron Ore is the second most important commodity in terms of seaborne trade (after oil) and employs about a third of the dry bulk shipping fleet in the world (Umunnakwe, 1987). Nigeria, as a geopolitical entity, possesses abundant reserves of iron ore and varying characteristics that render them suitable for steel making that can turn this nation to a great giant in the manufacturing of cars through the production of flat sheets, production of all types of machinery for industrial activities, manufacturing of military hardware, and eventually becoming a world power, etc. According to the words of Umunnakwe (1987), steel is strength and a nation's security must therefore derive from steel's various military applications. Iron ore deposit abound in different parts of the country as shown in table 1.

Table 1: Major Iron Ore Deposits in Nigeria.

Location	Geological description	Type	State	Approximate reserve	Grade
Agbaja	Sedimentary oolitic brown iron ore	Siderite	Kogi	1,159 mt	47.6
Ajabanoko	Precambrian banded ferruginous quartzite	Hematite slash Magnetite	Kogi	60 mt	40.0
Itakpe	Precambrian banded ferruginous quartzite	Hematite slash Magnetite	Kogi	200 mt	36.8
Koton Karfi	Sedimentary oolitic brown iron stone		Nasarawa	803 mt	52.9
Muro Hills	Precambrian banded ferruginous quartzite	Hematite	Plateau	Large	31.6
Choko Choko (Iyelu)	Precambrian banded ferruginous quartzite	Hematite	Nasarawa	12 mt	
Precambrian banded ferruginous quartzite	Hematite	Kwara		60 mt	
Darkin Giri	Precambrian banded ferruginous quartzite	Hematite	Zamfara	Vast-under investigation	
Egeneja	Sedimentary oolitic brown iron stone		Benue	369 mt	45.7
Nsude			Anambra	40.6 mt	40.0
Tajimi		Hematite	Kwara	under investigation	Under investigation

Nigeria is at the verge of diversification of her foreign exchange earnings and avoidance of over dependence on the petroleum sector. One very important way through which the nation can do this is by efficient and effective exploration and exploitation of her vast Iron Ore deposits and by extension her richly endowed huge solid mineral deposits spread all over the geopolitical zones of the nation. That the nation Nigeria is richly blessed with all sorts of mineral resources cannot be over emphasized. It is only now left for a dynamic and a proactive government to put in place functional policies and measures that will bring about their viable extraction to ameliorate the huge economic woes of our people. All iron ore deposit in-situ requires to be subjected to preliminary fragmentation before other operations like loading, haulage and crushing can take place. Indeed, efficiency in drilling and blasting determines efficiency in the other operations like loading, haulage and crushing. Saliu and Akande (2007) opined that blasting in Nigeria for years has been done on a hit-or-miss basis. The blaster would on the basis of experience chose the drilling and blasting pattern that would likely give the desired result without considering the structural geological condition of the rock. Drilling and blasting should be used to achieve in-situ rock breakage (fragmentation) if the spacing index of the deposit is greater than 2 and point load index greater than 3.0 MPa (Pettifer and Fookes, 1994). Saliu and Akande (2007) opined that blasting patterns in mines are optimized over months or even years with the help of trial blasting, particularly in the early stages of mine development. Blast optimization refers to method of attaining a cost-effective blast at zero environmental damage. The first step to mining cycle would be the drilling of a round for bench blast (Budin et al, 2003). Measurement of hole position and actual hole depth are the basics of this category (Rodgers, 1999). Blasting is a primary means of extracting minerals and ores at surface mining operations (Bajpayee

etal, 2004). The influencing factors of the fragmentation results in bench blasting are the mechanical properties of the rock mass and the design of the blast i.e. geometry, explosives, ignition pattern and delay times (Bergman, 2005).

Agoshkov et al (1988) in assessing material transportation stated that truck haulage is the most common means of transporting ore and waste from open-pit mines because trucks provide a more versatile haulage system at a lower capital cost than rail or conveyor systems in most pits. Further, trucks are sometimes used in conjunction with rail and conveyor systems where the haulage distance is greater than 3 or 5 km. Most haulage trucks can ascend road grades of 8 to 12% fully loaded. The size of trucks used is primarily dependent upon the size of the loading equipment, but the required production rate and the length of haul are also factors of consideration.

Shuey (1999) opined that it is usually the match-up of truck and loader that specifies the required loader size. A financial balance must be met when determining the optimum number of passes the loader must make to load the truck based on fleet size, travel distance and ore grade. The maneuverability and speed of a wheel loader make it ideal as a backup for shovels and excavators at sites where wheel loaders are not used for ore loading. Fiscor (2004) stated that in general, there are broad guidelines that steer buyers toward or away from certain type of loading machine. The link between truck and excavator capacities is important. While in some operations 6–7 passes are used to load trucks, 3–4 passes are considered optimum productivity. To maintain the 3–4 pass match, bucket sizes have had to increase, resulting in heavier excavators with more powerful engines and hydraulics. Hitachi's EX 1200 is slightly heavier at 108 tonnes in standard backhoe form, 109 tonnes for the bulk excavation version and 111 tonnes for the shovel variant. Bucket sizes ranges

from 3 – 7.1 m³ in backhoe and 5.9 – 6.5 m³ in shovel configuration. The EX 1200 makes a good match for a 46 tonne (50 US ton) capacity truck. Cat's 125 tonne 5110B is bridging the important gap in the range between the 84 tonne class 5080 and the 176 tonne 5130. Standard bucket sizes for the 5110B backhoe are 6.2 and 7.6 m³. The 5110B cycles in just 24 seconds can load a 53 tonne capacity truck in four passes or a 91 tonne payload truck in seven passes.

Thomas (1973) opined that it is accepted as a rule-of-thumb that to replace a shovel on permanent loading arrangement, a front-end-loader should have about double the bucket capacity of the shovel to give equal output. A shovel swings to load but the front-end-loader has to reverse out of the pile and turn before loading. But Dubnie (1975) stated that one rule of thumb used to estimate the performance of power shovels and loaders is that the shovel, loading with a normal swing of 90 degrees, will load approximately the same amount of material in a fixed time as front-end-loader with double the bucket capacity. This would probably not hold where the material is very fine (crushed) and the front-end-loader is very large. Agoshkov etal (1988) pointed out that the front-end-loader shortcomings include impossibility of working high benches (above 10 m) because of working member limitations, insufficient thrust for cutting medium rock and loading the bucket with coarsely broken rock.

Finally, Thomas (1973) pointed out that trucks for civil engineering construction are often quoted in body cubic capacity but for mining a large range of minerals of variable density it is better to quote load capacity in tonnes. A truck that could carry 40 m³ of coal might well break down if loaded with 40 m³ of iron ore.

1.1. Geology.

The Itakpe iron ore deposit is seen as a Precambrian iron formation located within the gneiss-migmatite-quartzite unit. it is of Nigerian basement complex and comprises over 25 individual ore bodies (14 being most prominent, 3 to 40 m thick each, over a total thickness of 600 m including intermediate layers of gneiss, migmatites, amphibolites, etc.), that are interbanded with migmatites, gneisses, schist's, amphibolites, quartzite's and intruded in places by granites, pegmatite's and haplites, all of which form a ridge over 4 km long generally trending East-West and dipping Southwards. The ore bodies outcrop on the surface in some places, in other areas they are covered by the over-burden that could be as much as 3 m.

Itakpe Iron Ore Deposit consists of ore veins of various width and length: width ranging from 1 to 24 m, and length ranging from 10 to a little over 100 m. The veins are almost vertical, dipping generally 800 southwards. The ore veins are separated from each other by various types of rocks; hard and soft. The iron ore body, though found in coarse, medium and fine grained formations, is generally consolidated, hard and abrasive. To extract the ore from its natural environment requires more than the earthmoving equipment (Borisade ,1987). The consolidation, hardness and abrasiveness jointly make it unavoidably necessary for blasting to take place to win the ore (Borisade, 1987).

1.2 Reserve Estimation and Life Span of Itakpe Iron Ore Deposit.

The Itakpe ore reserve is estimated as follows:

- (i) proven commercial reserve = 20 million tons;
- (ii) indicated reserve = 75 million tons;
- (iii) inferred reserve = 95 million tons;

Total geological reserve = 195 million tons.

However, mineable reserve is 158 million tons. The National Iron Ore Mining Project had a life span of 25 years at the production capacity of 6 million tons per annum.

1.3. Mineable Ore Reserve.

The mineable ore reserve of a deposit is that percentage which is exploited out of the total geological reserve. The mineable ore reserve of Itakpe deposit should be calculated using the following formulae:

$$B = (Si + Si + 1 L) / 2 \dots\dots\dots 1$$

The areas, volumes and tonnages of ore bodies on 15 cross-sections are shown in Table 3.1.

Table 2. Areas, Volumes and Tonnages of Ore-bodies.

Cross section	Area, m ² .	Volume, V ³ .	Tonnage, T.
1	56,000	2,900,000	10,440,000
2	60,000	2,925,000	10,530,000
3	56,000	2,800,000	10,080,000
4	55,000	2,975,000	10,710,000
5	64,000	3,375,000	12,150,000
6	71,000	3,300,000	11,880,000
7	61,000	3,400,000	12,240,000
8	75,000	3,675,000	13,230,000
9	72,000	3,200,000	11,520,000
10	56,000	2,862,500	10,305,000
11	58,000	3,040,000	10,944,000
12	63,000	3,200,000	11,520,000
13	65,000	3,190,000	11,484,000
14	62,000	3,150,000	11,340,000
15	64,000		
Total		43,992,500	158,373,000

The total ore reserves in tons = 43,992,500 x 3.6 = 158.4 million tons. Where 3.6 – is specific gravity of Itakpe iron ore. Therefore, the mineable ore reserve of Itakpe = 158.4 million tons.

1.4. Optimum Production Rate of the Mine.

The optimum production rate of Itakpe mine can be calculated using this formula:

$$P = (22.5 B) / (420 + B) \dots\dots\dots 2.$$

$$= (22.5 \times 158.4) / (420 + 158.4) = 6.16 \text{ million tons.}$$

$$\approx 6 \text{ million tons per annum.}$$

1.4.1 Life Span of Itakpe Mine.

The life span of Itakpe mine can be calculated using this formula:

$$B/P \dots\dots\dots 3.$$

$$= 158.4 / 6.16 = 25.7 \text{ years}$$

Itakpe mine could last for about 26 years.

1.5. Gestation Period (Development).

Gestation period is often 15-20% of overall life span of the mine. After this period, the mine is expected to generate profit and begin to finance itself. Applying this statistical data to Itakpe mine, period of development will range from 4-5 years.

$$\text{i.e. } (15 / 100) \times 25.7 = 3.855 \approx 4 \text{ yrs.}$$

$$\text{And } (20 / 100) \times 25.7 = 5.14 \approx 5 \text{ yrs.}$$

1.6. Pilot Mine and Assay Laboratory.

After the laboratory tests which included the systematic study of 267 core samples taken over the whole deposits; this has made it possible to define the main beneficiation parameters of each sample, such as the liberation mesh, the iron content, hematite/magnetite ratio, quality and weight recovery of the concentrate obtained by sink and float analysis and low intensity magnetic separation. So, it has been to characterize several faces inside the ore body in relation to the grain mesh of the iron bearing minerals, iron ore content of the ore, and importance of the magnetite in comparison to hematite. These faces are relatively separated when considered on a small scale. However, it is possible to divide the ore body into reasonably large areas where, on average, the mineral grain size mesh (and consequently the liberation mesh) is either coarse (approximately 1 mm), or medium (a few hundreds of microns) or sometimes fine (minus 200 microns). These various laboratory tests have shown that it was possible to obtain:

A sinter feed at 1.6 mm assaying 63 to 65% Fe on an average, with a good iron recovery, a super concentrate, after regrinding at 0.08 mm of the previous concentrates and reverse flotation, with a good iron recovery.

After the assay analysis, pilot tests were carried out using a 100 ton sample collected from the adit driven unto the deposit. Its mineralogical composition was close to the most frequent faces occurring in the deposit, i.e. characterized by and intermediate mineral grain size mesh and a hematite/magnetite ratio of 3:2. In particular the following techniques were tested during the pilot investigations.

Semi-autogenously grinding using a 1.6 m diameter mill: this made it possible to define the parameters for industrial grinding (screening mesh, circulating load value, specific grinding power, necessary ball loading) in order to obtain a ground product with the required grain size for the subsequent phases of treatment.

Gravity beneficiation using a spirals circuit. These tests have shown that the best circuit was one with a roughing spiral stage giving a final reject (at approximately 11% Fe contents) followed by two spiral cleaning stages make it possible to obtain a final spiral concentrates assaying 63 to 65% Fe according to the wash water.

i. Low intensity magnetic separation, in particular on the fine fractions (minus 100 microns) and on the gravity separation rejects in order to recover the

magnetic grains and the hematite-magnetite middling grains not collected by the spirals.

iii. Production of super-concentrates by regrinding of the gravity concentrates des-liming and flotation. Several tons of concentrates have been treated in a continuous pilot circuit at a rate of 100 kg/hr. by regrinding at minus 100 microns, followed by reverse flotation 9.5 tones of super-concentrates assaying 68.5% Fe and less than 1.5% SiO₂ have been produced. Starch was used as an iron oxide depressant and amines as a collector for quartz and silicates.

iv. Discontinuous filtration tests on enriched products fractions, as well as measurement of the work index and the abrasivity index for several ore faces have been carried out.

v. Also sintering tests have been carried out using the gravity concentrates (grain size: < 1.6 mm) as well as palletizing and direct reduction tests using the super-concentrates.

2. Materials and Methods.

In 1992, a production target of 1 million tons per annum of run-of-mine (ROM) ore was set for mine production teams. In order to step up production in the mine, three shifts were introduced early January 1991, and a lot of incentives and bonuses were handed down to the mine workers. The mine activities included drilling and blasting, loading and haulage of the blasted ores to the iron ore stockpiles and waste materials to the waste dumps. The introduction of the three shifts provided avenue for healthy competition and subsequently, improve annual production. In the cause of production of run-of-mine (ROM) ore, the production target of 1 million tons per annum was never attained rather, 412,000 tons of run-of-mine (ROM) was produced representing 41.2% of the required production target. Due to this shortfall in production target a comprehensive analysis of the equipment fleet of each unit operation was carried out with a view to finding out the real source of the bottle-neck in the production system.

The methodologies of this research work were to list out all the production equipment and monitor strictly their day to day operations with the possibility of identifying the source of lapses in the production target. The production equipment available in NIOMCO at the period of this investigation is listed below:

- i. For drilling and blasting: 1 (one) ROC 608;
2 (two) ROC 404;
- ii. For loading Operations: 2 (two) 950C loaders;
2 (two) 980C loaders;
- iii. For haulage Operations: 3 (three) R35 dump trucks

2.1. Nomenclature.

The following symbols are used for various calculations.

- S_i – Area of ore body on i^{th} cross-section, m^2
- S_{i+1} – Area of ore body on $i^{\text{th}} + 1$ cross-section
- B – Mineable ore reserve, million tons
- A – Optimum production rate of the mine, million tons
- d – Drilling bit diameter, mm
- E – Blast hole spacing, m
- v – Blast hole burden, m
- Q – Production rate, m^3
- N – Number of working days in a year, days
- n_{sh} – Number of shifts per day
- p – Proportion of working time spent purely on drilling
- s – Drilling rate, m/hr
- t – Duration of a shift, hrs
- V – Bucket capacity, m^3
- η – Production time utilization factor
- k – Bucket capacity utilization factor
- t_{cy} – Cycle time of equipment

2.2 Drilling and Blasting Operation

(i) ROC 608 (1 No).

Specifications: $d = 89 \text{ mm}$; $E = 35 d = 35 \times 89/1000 = 3.12 \text{ m}$; $v = 0.85$

$$E = 0.85 \times 3.12 = 2.65 \text{ m.}$$

$$Q = N \times n_{sh} \times t \times p \times s \times E \times v, m^3 \dots\dots\dots 4.$$

$$Q = 220 \times 3 \times 8 \times 0.4 \times 15 \times 3.12 \times 2.65 = 261,930 \text{ m}^3.$$

(ii) ROC 404 (2 No).

Specifications: $d = 115 \text{ mm}$; $E = 35 d = 35 \times 115/1000 = 4.03$; $v = 0.85 \times$

$$E = 0.85 \times 4.03 = 3.42 \text{ m.}$$

$$Q = N \times n_{sh} \times t \times p \times s \times E \times v =$$

$$= 220 \times 3 \times 8 \times 0.4 \times 15 \times 4.03 \times 3.42 =$$

$$= 436,633 \text{ m}^3.$$

Total productivity of the 3 drilling rigs,

$$QT = [(1 \times 261,930 \text{ m}^3) + (2 \times 436,633 \text{ m}^3)] \times 0.45 \times 3.6$$

$$= 1,839,017 \text{ tons.}$$

Where, 0.45 – capacity utilization of NIOMCO drilling equipment.

3.6 T/M^3 – density of ore.

2.2 Loading Operations:

(i) Loader 950C (2 No).

Specifications: $V = 3 \text{ m}^3$; $N = 220$ days; $n_{sh} = 3$; $t = 8$ hrs; $\eta = 0.8$;

$$k = 0.7; t_{cy} = 50 \text{ sec.}$$

$$Q = (3600 \times N \times n_{sh} \times t \times \eta \times V \times k, m^3) / t_{cy} \dots\dots\dots 5.$$

$$= (3600 \times 220 \times 3 \times 8 \times 0.8 \times 3 \times 0.7) / 50$$

$$= 638,669 \text{ m}^3 \text{ or } 2,299,208 \text{ tons}$$

For 2 No: $Q = 2 \times 2,299,208$

$$= 4,598,416 \text{ tons.}$$

(ii) Loader 980C (2 No):

Specification: $V = 5 \text{ m}^3$;

$$Q = (3600 \times 220 \times 3 \times 8 \times 0.8 \times 5 \times 0.7) / 50$$

$$= 1,064,448 \text{ m}^3 \text{ or } 3,832,013 \text{ tons.}$$

For 2 No.

Production Rate, $Q = 2 \times 3,832,013 = 7,664,026$ tons.

Total production rate of loading equipment:

$$2 \text{ NO. } 950\text{C} + 2 \text{ NO. } 980\text{C} = (4,598,416 + 7,664,026) \times 0.45$$

$$= 5,518,099 \text{ tons.}$$

Where, 0.45 – loading equipment capacity utilization due to maintenance problems (i.e. lack of spare parts).

2.3 Haulage Operations.

(i) Dumper R35 (3 NO).

Specification: $V = 35$ tons.

$$Q = (60/tcy) \times V \times \eta \times N \times n_{sh} \times t \times k \times C =$$

$$= (60/15) \times 35 \times 0.8 \times 220 \times 3 \times 8 \times 0.7 \times 0.45 = 199,584 \text{ tons.}$$

Where, η – dumper tonnage utilization factor; k – production time utilization factor; C = capacity utilization of the haulage equipment due to maintenance problems.

3. Evaluation of Specific Costs of Unit Operations in NIOMCO.

To estimate the specific costs of unit operations, each unit operation is considered with respect to the following: material cost, energy cost, labor cost, etc. The different unit operations in NIOMCO are as follows:

(I) Drilling, (ii) Blasting, and (iii) Mucking and Haulage. A. Drilling:

In drilling cost, a set of compressor and ROC drill is employed.

Cost Analysis:

A. Drilling Equipment.

· Initial Investment on the compressor and ROC Drill

$$= \text{\#}88,200,000$$

· Estimated life of compressor and ROC Drill

$$= 5 \text{ years}$$

· Depreciation per day

$$= (88,200,000) / (5 \times 220) = \text{\#}80,182$$

· Fuel consumption

$$= 30 \text{ liters/hr}$$

(But there are five effective working hours per day)

Therefore,

· fuel consumption per day

$$= 30 \times 5 = 150 \text{ liters} = N \text{ } 18,000$$

· Hydraulic consumption per day

$$= \text{\#}1000$$

· Lubricant (10% of fuel consumption per day + grease)

$$\backslash = \text{\#}1800$$

· Spare parts (10% of depreciation per day)

$$= \text{\#}8,018$$

· Total cost per day = $\text{\#}109,000$.

B. Drilling Accessories:

(i) Drill steel rod.

· Cost of one drill steel

$$= \text{\#}6,000$$

· Estimated life of rod

$$530 \text{ m}$$

E. Personnel:

- | | | | |
|-----------------------------|---------------------------------|-------------|-----------|
| 1. Compressor and ROC Drill | - 2 persons | | |
| ii Bulldozer | - 2 persons | | |
| iii Pay loader | - 2 persons | | |
| iv. Dump truck | - 2 persons | | |
| v. Maintenance | - 2 persons | 6. Blasters | 4 persons |
| vi. Security | -2 persons | 22 | 220 |
| vi. Administratio | - 3 persons = N 88,864 per day. | | |
| viii Supervisor | - 1 person | | |

All the workers received an average salary of Grade Level, GL 05/4 with the exception of the supervisor, who is on GL 09/4.
 $= [(GL\ 05/4) \times 19 + (GL\ 09/4) \times 1] / 220$
 $= [(950,000 \times 19) + (1,500,000)] / 220$
 $= N\ 88,864\ per\ day.$

4. Results and Discussion:

The summary of the analysis on the production fleet above shows that

- i. Drilling equipment fleet could produce 1,839,018 tons \approx 1.84 million tons;
- ii. Loading equipment = 5,518,099 tons \approx 5.52 million tons;
- iii. Haulage = 598,752 tons \approx 0.6 million tons.

From the above, it can be seen that even though equipment fleet in drilling and blasting unit and in the loading operations unit could produce well above one million tons of run-of-mine ore per annum, the equipment fleet in the haulage unit were highly inadequate. This explains why the one million tons target set in 1992 by the General Manager and Chief Executive, Engr. A. D. Famuboni, was not achieved. Hence, there was an urgent need to purchase more dump trucks, which was then the bottleneck in the production system. Other problems included the thick volume of dust generated during drilling and haulage operations. In order to minimize the harmful effect of dust on the mine workers, the management was encouraged to procure a water sprinkler that should ply the haulage routes and eventually suppress the dust level during haulage. For the drilling equipment also, the dust extractor was recommended to management and it was purchased thereby reducing the volume of inhaled dust by the drilling operators. Also, in the evaluation of specific costs analysis of unit operations the summary of costs is depicted in table 3.

For further clarification of table 3.

- 1a. For drilling operation: the total cost of utilizing drilling equipment for a day amounted to NGN109/day (page 9).
- b. The total cost of drilling accessories per meter is NGN52/m (page 10). But there is a total of 420m of holes achievable per day.

Therefore, $52 \times 420 = NGN21,840/day.$

In other to convert these figures to NGN/day production, remember that the run-of-mine (ROM) production rate per day is 19,855tons/day (page 12). Then, it will become NGN6.5 ton/day.

Table 3. Summary of Cost.

Parameter	Cost/day, NGN/m.	Cost/day, NGN/day.
(1) Drilling Cost: Compressor and ROC Drill Consumables		
	109,000	
	52×420	5.490
	$= 21,840$	
		1.01
(2) Blasting Cost: Explosives Accessories		
	350×420	
	$= 147,000$	25
		7.4
(3) Mucking:		
Bulldozer Pay loader	118,800	5.98
	80,260	4.04
(4) Haulage:		
Dump truck	131,200	6.61
(5) Personnel		
	88,864	4.48
Total production cost =		
	696,964	N
		60.01/ton.

NB. The achieved production rate of run-of-mine ore (ROM) was 19,855 tons/day.

Hence the results of NGN5.490/day and NGN1.01/day respectively. Etc.

From the final analysis, it is evident that the general cost of production of one ton of run-of-mine ore (ROM) is NGN60.

5. Conclusion.

Drill, blast, muck and haul still remain the most cost effective method of winning the ore in hard rock formation. The equipment and machinery involved are always matched with each other so as to avoid delays in the production value chain. From the engineering design of blast holes, adequate blast holes are mapped out in the drilling chain that will keep the haulage crew busy before the next round of blast could be effected. Therefore proper selection of these equipment and machinery is done to match unit operation. It is expedient to note that efficiency in drilling and blasting determines efficiency in the other operations like mucking, haulage and crushing. Costing of these unit operations is also carried out to ascertain the cost of producing a unit ton of run-of-mine (ROM) ore. This is in turn to boost the investor's/employer's confidence and for him at a glance envisage the capital outlay of the proposed project. This is implemented according to the principle of equipment cost, material (consumables) cost and labor cost. At the final analysis, the unit cost of producing a ton of iron is provided and in this particular case amounted to NGN60/ton.

Depreciation per drill meter $6000/530 = \# 11.3 / \text{m}$

(ii) Drill bit (button bit).

· Cost of one drill bit = N 6,000
 · Estimated life of a drill bit 200 m
 · Depreciation per meter $6000/200$
 = #30/m

(iii) Shank adaptor sleeve.

· Cost of one shank adaptor sleeve = #4,000
 · Estimated life 800 m
 · Depreciation per drill meter $4000/800$
 = #5/m.

(iv) Coupling sleeve.

· Cost of one coupling sleeve = #3,000
 · Estimated life 530 m
 · Depreciation per drill meter $3,000/530$
 = #5.7/m

Total drill cost $\# (11.3 + 30 + 5 + 5.7) = \#52/\text{m}$.

However, about 420 m is achieved per day through drilling.

C. Blasting:

(i) Explosives.

· Cost of one ton of high explosives
 = # 250,000
 · Cost of one ton of ammonia nitrate plus fuel oil
 = # 1,000,000
 · But explosive consumption (powder factor)
 = 200 g/ton
 · High explosive consumption (15%)
 $= (0.15 \times 250,000 \times 0.2) / 100 = \#7.5$
 · ANFO consumption (85%)
 $= (0.85 \times 100,000 \times 0.2) / 1000 = \#17.00$

Total cost of explosives per ton blast

= # 25.

(ii) Blasting accessories.

· Cost of prima-cord per meter
 = # 50
 · Cost of safety fuse per meter blast
 = # 150
 · Cost of delay detonator per piece
 = # 150

Total blasting cost

= # 350/m

D. Mucking and Haulage:

(i) Mucking with Bulldozer D8K.

· Initial investment on the bulldozer
 = # 87,600,000
 · Estimated life of a bulldozer 5 years
 · Depreciation of the bulldozer per day
 $= (87,600,000) / (5 \times 220) = \#79,636.4$
 · Fuel consumption =

45 liters/hr.

(but there are 5 effective hours of the equipment per day)

· Therefore, fuel consumption per day $= 45 \times 5 = 225 \text{ liters/day}$

· Cost of fuel consumption per day
 $= 225 \times 120 = \# 27,000$

· Lubricant (10% of fuel consumption per day + grease)
 $= \#2,700$

· Hydraulic consumption per day
 $= \# 1,500$

· Spare parts (10% of depreciation per day)
 $= \#7,963.6$

Total: = #118,800.

(ii) Loading with Pay Loader.

· Initial investment of the pay loader
 $= \#55,000,000$

· Estimated life of a pay loader
 $= 5 \text{ yrs or } 10,000\text{hrs}$

· Depreciation of pay loader per day $= 55,000,000/5 \times 220$
 $= \#50,000$

· Fuel consumption = 36 liters/hr.

(But there are five effective working hours per day)

· Therefore, fuel consumption per day $= 36 \times 5 = 180$
 liters/day

· Cost of fuel consumption per day
 $= 180 \times 120 = \# 21,600$

· Lubricant (10% of fuel consumption per day + grease) =
 $\#2,160$

· Hydraulic consumption per day
 $= \# 1,500$

· Spare parts (10% of depreciation per day)
 $= \# 5,000$

Total: = # 80,260.

(iii) Haulage with dump truck.

· Initial investment on the truck
 $= \# 100,000,000$

· Estimated life of truck
 $= 5 \text{ years or } 10,000 \text{ hrs}$

· Depreciation of the truck per day
 $= 100,000,000/5 \times 220$
 $= \# 90,909$

· Fuel consumption = 45 liters/hr.

· Cost of fuel consumption per day
 $= 225 \times 120 = \# 27,000$

· Lubricant = # 2,700

· Spare part = # 9,091

Total: = #131,200

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