TECHNICAL AND FINANCIAL ASSESSMENT OF HEMATITE (IRON ORE) EXTRACTION FROM IRON DEPOSITS OF POKHARI AREA, NAWALPARASI

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Abstract

Iron and Steels is one of the top three major imports of Nepal. Based on the fact that Nepal has large amount of mineral resources, it is important to explore and exploit them rationally. This research paper is carried out to estimate the iron ore reserve of the iron ore deposits of Pokhari in Nawalparasi which was recently discovered by Department of Mines and Geology (DMG), Nepal. In this research work, the technical and financial assessment of hematite (iron ore) extraction of iron deposits of Pokhari, taking an area of one square kilometre, has been carried out. The tonnage of iron ore and the over-burden (which is quartzite and slate in this case) were estimated considering the mining process to be open cast mining using vertical cross-section method. The depth of hematite zone is taken as 100 m. The iron ore to over-burden (waste) ratio was 1:3.36. The financial analysis was done on the basis of extraction of 3600 metric tons of iron ore per day and 8,64,000 metric tons annually. The return on investment (ROI) is 34%. Thus, the research work indicates that the extraction of large amount of iron ore of Pokhari area is economical and it is a beneficial project.

Keywords: Hematite (iron ore), Extraction, Pokhari (Nawalparasi), vertical cross-section method, ROI

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1.   Introduction

Iron (Fe) is the principal metal which is used extensively in infrastructure development works, and to manufacture heavy machinery equipment, arms and agricultural tools. Iron ores like magnetite, hematite, limonite/goethite occurrences/ prospects/ deposits are known to exist in more than 85 localities. Some of these ores were extensively mined and smelted in different parts of Nepal for 150 years till 1951 (2007 BS) but none of these mines are in operation since then. The well-known iron ore deposits are Phulchoki (Lalitpur), Thoshe (Ramechhap), LabdiKhola (Tanahun), Jirbang (Chitwan), Dhauwadi - Pokhari (Nawalparasi), Dhuwakot (Parbat), Bhedikhor and Lukarban (Baglung), Purchaundi/ Lamunigad (Bitadi), Dahabagar, Kachali, and Ekghar/ Khanigaon (Bajhang). Among the above mentioned mines of iron, the exploration work is being carried out at Dhauwadi-Pokhari (Nawalparasi).

The area is accessible by road and lies west of Kathmandu. Daldale Bazar is a market place in East-West Highway, from where a dust road of about 24 km runs north linking Dhauwadi. Similarly, from Chormara in the East-West Highway, a dust road of about 23 km links Pokhari through Jhyalbas. The rest of the area can only be accessed on foot (Fig.1).
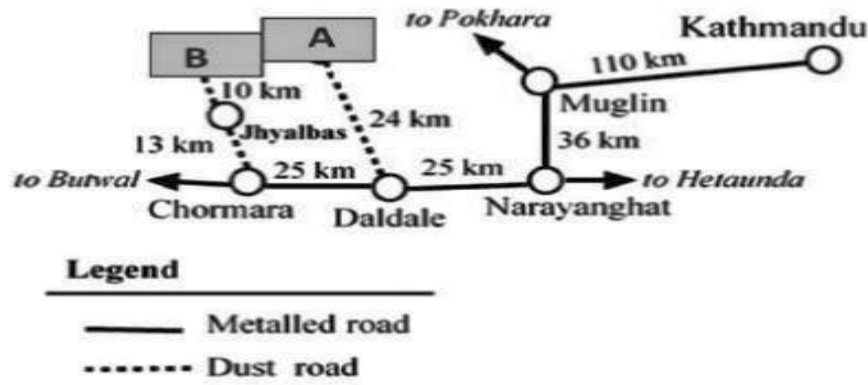
Figure 1: Accessibility to the Hematite deposit areas [1]

Block A lies in Topo sheet No. 100-09 (within Coordinates UTM of 3069000m to 3071500m North and 505500m to 510500m East) and Block B lies in Topo sheets 100-09 and 100-10 (within Coordinate UTM of 3070000m to 3072500m North, and 510500m to 515500m East). Both the areas extend for 5 km in east west direction and 2.5 km for north-south direction, each covering an area of 12.5 km^2, with a total of 25km^2. Here, Block A refers to Dhawadi and Block B refers to Pokhari of Nawalparasi district.[1]
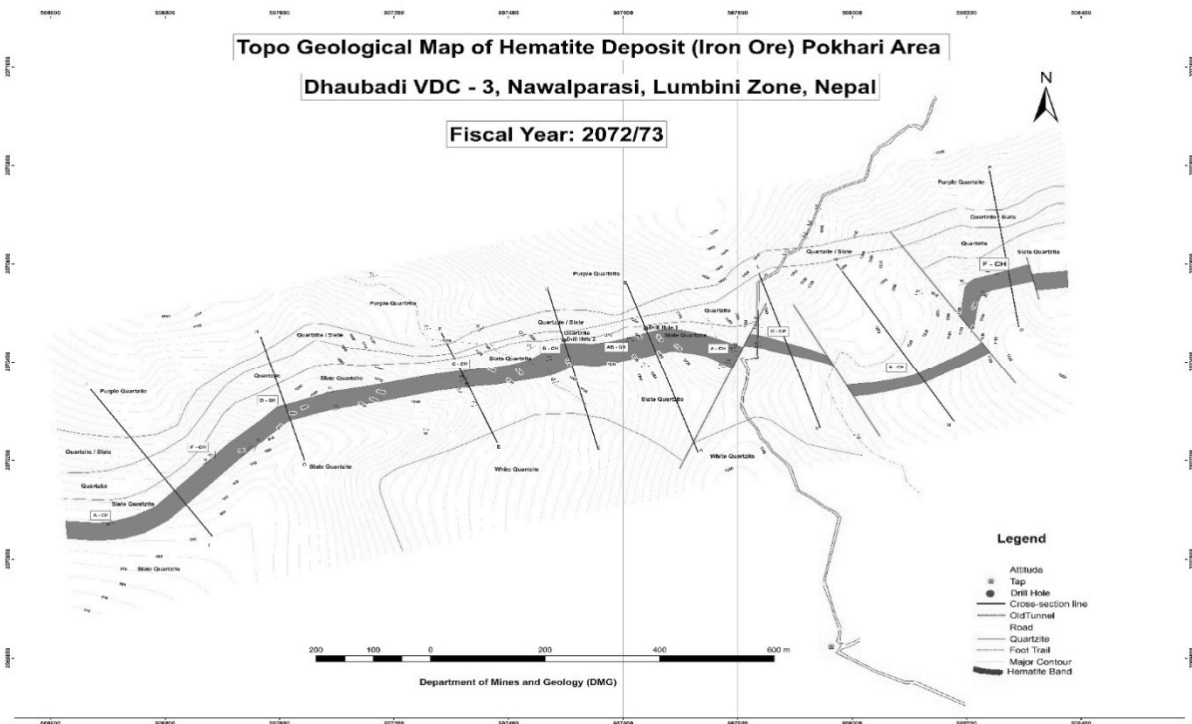

Figure 2: Topo geological map of hematite deposit of Pokhari area (Source: DMG)

2.   Research Methodology

Data Collection

The study assessed a large scale iron ore production from Pokhari iron ore deposit. The annual run-of-mine production per year is 8,64,000 tons. Facilities for the project were identified and their cost estimates were obtained from equipment fabricators and suppliers. The topo-geological map with the cross-section lines of hematite deposit (iron ore) of Pokhari area, Nawalparasi is one the baseline document collected from DMG. The strike length for each cross-section lines and percentage of hematite in hematite zone (which is 60%) are obtained from DMG.

Estimation of Reserve (Iron Ore) by Vertical Cross-Section Method

A geological cross-section is a graphical representation of the intersection of the geological bodies in the sub-surface with a vertical plane of a certain orientation. It is a section of the terrain where the different types of rocks, their constitution and internal structure and the geometric relationship between them are represented. It is an approximate model of the real distribution of the rocks in depth, consistent with the information available on the surface and the sub-surface. It can also represent the extension of the materials of the structures that have been eroded above the topographic surface.

The cross-sections are an indispensable complement of the geological maps; maps and cross-sections are fruit of the interpretation of the arrangement of the rocks using diverse types of data normally incomplete and with different degrees of uncertainty. Both are bi-dimensional representations of the geological reality and jointly allow us to understand the tri-dimensional structure of the rocky volumes and, in consequence, the geological history of a zone.

In vertical cross-section method, following steps are followed for the generation of geological cross-section and hence for the calculation of reserves (iron ore):

  i.   The length of vertical plane of the perpendicular orientation to the alignment of the rock is taken along the x-axis.
  ii.   The elevation of topo-geological map is taken along the y-axis.
  iii. The point of intersection of elevation and the length of the vertical plane of topo-geological map is plotted on the graph.
  iv.   The plotted points are joined together by the free line.
  v.   By the help of topo-geological map, the different sections (zones) are separated. The depth of hematite zone is taken to be 100 m for the generation of geological cross-section.

Since there are eight cross-section lines (vertical planes) along the topo-geological map of hematite deposit of Pokhari area, eight geological cross-sections are made and their respective cross-section areas of hematite zone are calculated by using above method in AutoCAD software.

After the calculation of the cross-section area of hematite zone, it is then multiplied with the strike length (which is different for different geological cross-sections) to get the volume of the hematite zone.

$$\text{Volume of the zone} = \text{Cross-sectional area} \times \text{Strike length}$$

Now, this volume is multiplied with the specific gravity of the rock (which is 4 for the hematite zone in this case) to get the tonnage of the hematite zone (in tons).

$$\text{Tonnage of the ore} = \text{Volume of the zone} \times \text{Specific gravity of the rock}$$

Since the percentage of hematite (iron ore) in hematite zone is not 100 % (which is 60% in this case), to get the actual reserve (iron ore), the obtained tonnage of the ore is multiplied by 0.6.

Estimation of Over-burden (Waste)

Since this research work of mining is assumed to be carried by open cast mining, the production of waste will be more. For the calculation of the over-burden, the following steps are undertaken:

i. The ultimate pit slope of 70° is taken from the bottom of the upper boundary of hematite zone in each geological cross-sections.

ii. The bench of 3 m vertical height is drawn from the intersection point of the profile of the geological cross-section and the slope line of 70° and joined to the slope line again another bench of 3 m vertical height is drawn in the same fashion. It continues upto the bottom of the upper boundary of hematite zone.

iii. The similar bench structure is drawn along the lower boundary of hematite zone.

iv. The cross-sectional area of the over-burden between the slope line and the upper boundary of hematite zone is calculated.

v. The cross-sectional area of the bench structure opposite to the hematite zone is calculated.

vi. The cross-sectional area of the bench structure along the hematite zone is calculated.

vii. The sum of the cross-sectional areas of (iv), (v) and (vi) is calculated.

viii. The sum of the cross-sectional areas of (vii) is then multiplied with the respective strike length to get the volume of the total over-burden.

ix. The volume obtained in (viii) is added to the volume of the waste of the hematite zone (which is 40% of the zone) to get the final volume of the total waste.

x. This volume is then multiplied with the specific gravity of the waste (which is 2.7 in this case) to get the tonnage of the total waste that can be generated in the process of mining.

Financial Analysis

The financial analysis has been carried out based on the following assumptions:

i. Annual production of iron is 8,64,000 tons at the rate of 3,600 tons per day.

ii. The mine runs for 240 days (8 months) in a year.
  a) Working shift in a day = 1 shift
  b) Working hour in a shift = 8 hours
  c) Effective working days in a month = 20-25 days
  d) Effective working months in a year = 8 months (240 days after considering holidays,festivals, rainy season)

iii. Cost estimation are based on prevalent market price or taken as consideration with the similar mining industry.

iv. Iron ore production cost up to mine stockyard has been estimated. The transportation of iron from stockyard to the market will be done in contract basis.

v. The relevant facilities and tax relaxation will be made on heavy machineries and equipment.

vi. The average grade of the iron ore is 40%.

Estimation of the cost of extracted iron ore per ton

The cost of extracted iron ore per ton is calculated by dividing the annual operating cost by the annual iron ore production.

Cost of extracted iron ore per ton = Annual operating cost / Annual iron ore production

3. Results and Discussions

Table 1: Reserve Estimation of Pokhari Area

Section	Cross Sectional Area, m²	Strike Length, m	Specific Gravity	Reserve, ton	% of Hematite	Reserve, million ton	Over-burden in Reserve, m³
AB	6032.507	225	4	5429256.3	60	3.25755378	542925.63
CD	6901.726	170	4	4693173.7	60	2.81590421	469317.368
EF	5384.732	260	4	5600121.3	60	3.36007277	560012.128
GH	6758.347	290	4	7839682.5	60	4.70380951	783968.252
IJ	5998.169	330	4	7917583.1	60	4.75054985	791758.308
KL	3885.696	155	4	2409131.5	60	1.44547891	240913.152
MN	4515.087	250	4	4515087	60	2.7090522	451508.7
OP	5835.321	215	4	5018376.1	60	3.01102564	501837.606
Total						**26.053447**	

Table 2: Estimation of Total Waste (Over-burden) of Pokhari Area

S.N.	Section	Cross Sectional Area of Over-burden, m²	Total Cross Sectional Area of Benches , m²	Cross Sectional Area of Total Over-burden, m²	Strike Length, m	Volume of Total Over-burden,m³	Over-burden in Reserve, m³	Total Waste,m³
1	AB	7106.822	247.055	7353.877	225	1654622.33	5711.853974	1660334.18
2	CD	9742.259	286.119	10028.378	170	1704824.26	7768.096783	1712592.36
3	EF	15881.129	363.658	16244.787	260	4223644.62	12923.02755	4236567.65
4	GH	22953.12	448.209	23401.329	290	6786385.41	20077.68391	6806463.09
5	IJ	19235.216	456.777	19691.993	330	6498357.69	20546.34781	6518904.04
6	KL	18815.915	458.879	19274.794	155	2987593.07	20755.0544	3008348.12
7	MN	16896.829	431.331	17328.160	250	4332040	17364.96133	4349404.96
8	OP	18815.915	411.404	19227.319	215	4133873.59	16734.77541	4150608.36
				Total				**32443222.8**

Tonnage of waste = Total volume of waste x Specific gravity of waste = 32443222.8 x 2.7

= 87596701.6 tons

Financial Analysis

Table 1:Open Pit Technical Parameters (Pokhari Iron Ore Mine)

SN	Parameter	Quantity	Unit
i	Ore reserve	26.05	million tons
ii	Life span	30	years
iii	Annual Ore production	864,000	tons
iv	Annual waste production	2,903,040	tons
v	Waste to Ore ratio	3.36:1	
vi	Daily Ore production	3,600	tons
vii	Daily waste production	12,096	tons
viii	Average Ore grade	40%	
ix	Minimum width of Pit bottom	50	m
x	Ultimate Pit slope	70	degree

The data given in table 3 shows the important parameters required for the process of mining.

Table 2:Facilities and Civil Structures (Pokhari Iron Ore Mine)

Pre-requisites of Mining

S. No.	Description	Quantity	Units	Unit Prices	Total Cost
				In lakhs (NRs.)	
1	Land and Lease				
A	Land Acquisition /Compensation	30	Hectors	60	1800
B	Site Development	7	Hectors	5	35
2	Access Road Construction	23	Km	250	5,750
3	Buildings (Office, Workshop and Laboratory)			200	200
4	Construction of Stock Yard and Dump Yard			25	25
5	Construction of Siltation Pond			8	8

6	Furniture and Fixtures			3	3
7	Office Equipments			2	2
8	Power Supply and Arrangements			35	35
9	Communication			2	2
10	Licensing fee			1000	1000
11	Report Writing			20	20
Total					**9,380**

Land acquisition and compensation, access road construction, site development, buildings for office, workshop and laboratory, construction of stock yard and dump yard, construction of siltation pond, power supply and arrangements, communication, furniture and fixtures, and office equipments are pre-requisites of mining. One should be able to develop all these infrastructures before exploitation of mines. Report writing containing the mining schemes and the plan, and licensing fee (tender) are pre-requirements before taking down the developments of the infrastructures of the mining.

Mine Machinery

					In lakhs (NRs.)	
S. No.	**Equipment Description**	**Capacity**	**Units**	**Quantity**	**Unit Prices**	**Total Cost**
1	Dump Truck	85	tons	10	300	3,000
2	Wheel Loader	10	m^3	4	600	2,400
3	Excavator	5.6	m^3	2	500	1,000
4	Bull Dozer	15	m^3	2	350	700
5	Breaker			2	30	60
6	Scraper			2	90	180
7	Roller			2	100	200
8	Pneumatic Drill Rig	15	m/h	3	60	180
9	Rotatory Drill Rig			2	200	400
10	Jack Hammer	3	m/h	4	4	16
11	Compressor	8	bar	2	40	80
12	Water Tanker	20,000	litres	1	30	30
13	Admin. Car			3	70	210
14	Workshop Van			3	90	270
15	Explosive Van			4	40	160

S. No.					Qty	Rate	Amount
16	Staff Buses				2	80	160
17	Gyratory Crusher				1	100	100
18	Primary Crushing Plant				1	500	500
19	Process Capital Cost				1	400	400
20	Drill Accessories and Exploder					10	10
21	Workshop Equipments						50
22	Safety Equipments						40
23	Lab Equipments						400
24	Incidental						100
	Total						**10,656**

The mine machinery mentioned in the above table are used for different purposes implied in the open cast mining process. Pneumatic drill rig, rotary drill rig and jack hammer are used for drilling task. The wheel loader and excavator are employed in loading task. Dump truck of high capacity are used in haulage of ore in mining process.

S. No.	Description	Total Cost, In Lakhs (NRs.)
1	Pre-requisites of Mining	9,380
2	Mine Machinery	10,656
	Sub-Total	**20,036**
3	Contingency (5%)	1001.8
	Total Fixed Capital Investment	**21,037.8**

The contingency taken for the given project is 5%. Hence, the total fixed capital investment is NRs. 21,037.8 lakhs.

Annual Operating Cost

The annual operating cost is divided into fixed operating cost and variable operating cost.

Fixed Operating Cost

The fixed operating cost consists of the following costs:

Depreciation

S.No.	Particular	Total Cost (NRs.)	Depreciation Rate, %	Depreciated Amount (NRs.)
1	Mine machinery	1,05,56,00,000	10	10,55,60,000

The rate of depreciation of the mine machinery is taken as 10%.

Insurance

S.No.	Particular	Total Cost (NRs.)	Insurance Rate, %	Insurance Amount (NRs.)
1	Mine Machinery	1,05,56,00,000	2	2,11,12,000

The rate of insurance of mine machinery is taken as 2%.

Land Renewal charges

S.No.	Particular	Amount (NRs.)
1	Renew	5,00,000

The land renewal charges per year is NRs. 5,00,000 as per DMG.

Salary and Wages

The personnel employed in mines is divided into two divisions: corporate division of mines and production division of mines. The salary and wages of persons calculated is of 13 months except that of labours employed on the monthly basis. The benefits is also given to the employees which is 15% of their annual salary.

S.No.	Corporate Division of Mines	Quantity	Monthly (NRs.)	Total Amount (NRs.)
1	Mines Manager (Senior Mining Engineer)	1	50,000	6,50,000
2	Production Manager (Mining Engineer/Geologist)	2	40,000	10,40,000
3	Geologist (Quality and Exploration)	2	35,000	9,10,000
4	Administrative Officer	2	30,000	7,80,000
5	Account Officer	2	30,000	7,80,000

6	Procurement/Store Officer	1	30,000	3,90,000
7	Mining Foremen	5	25,000	16,25,000
8	Mechanical Foremen	7	25,000	22,75,000
9	Surveyor	3	20,000	7,80,000
10	Computer Operator	3	18,000	7,02,000
11	Office Assistants	4	16,000	8,32,000
12	Driver	8	15,000	15,60,000
13	Peon / Guard	5	14,000	9,10,000
	Sub Total	**45**		**1,32,34,000**
	Benefits		15%	19,85,100
	Total (Corporate Division)			**1,52,19,100**

S.No.	Production Division of Mines	Quantity	Monthly (NRs.)	Total Amount (NRs.)
1	Mine Supervisor	2	20,000	5,20,000
2	Mechanic	3	20,000	7,80,000
3	Driller	9	18,000	21,06,000
4	Electrician	2	18,000	4,68,000
5	Blaster	5	18,000	11,70,000
6	Operator (compressor)	2	17,000	4,42,000
7	Operator (heavy equipments)	20	17,000	44,20,000
8	Assistants	20	15,000	39,00,000
9	Labours(monthly basis-8 months)	100	14,000	1,12,00,000
	Sub Total	**163**		**2,50,06,000**
	Benefits		15%	37,50,900
	Total (Production Division)			**2,87,56,900**

Hence, the total fixed operating cost is NRs. 17,11,48,000.

Variable Operating Cost

The variable operating cost consists of the following costs:

S.No.	Particular	Amounts (NRs.)
1	Office Overhead	30,00,000
2	Power Charge	30,00,000
3	Annual Supply (Material) Cost	2,00,00,000
4	Fuel Cost	20,00,00,000
	Total	**22,60,00,000**

Repair and Maintenance

S.No.	Particular	Total Cost (NRs.)	Maintenance Rate, %	Amount (NRs.)
1	Mining Machinery	1,05,56,00,000	5	5,27,80,000
2	Road and Civil Works	93,80,00,000	2	1,87,60,000
3	Haulage / Track Maintenance			1,00,00,000
	Total			**8,15,40,000**

The rate of maintenance for the mining machinery is taken as 5% whereas that for road and civil works is taken as 2%. The haulage and track maintenance is necessary as during the course of mining its condition gets deteriorated.

Explosive Cost

S.No.	Description	Unit	Quantity	Unit Rate (NRs.)	Amount (NRs.)
1	Explosive	Ton	1,260	71,500	9,00,90,000

The cost for explosive is calculated on the basis that one ton of explosive produces 3000 tons of ore and the cost for one ton of explosive is NRs. 71,500.

Production Royalty

S.No.	Particular	Production (tons)	Rate (NRs.)	Amount (NRs.)	Remarks
1	Royalty	8,64,000	40 per ton metal	1,38,24,000	40% of Fe

2	Local Body		10% of royalty	13,82,400	
	Total			**1,52,06,400**	

The royalty given to the government of Nepal is NRs. 40 per ton metal. Since the content of iron in iron ore (hematite) is assumed to be 40%, the total amount is calculated to be NRs. 1,38,24,000. The local body also charges 10% of the royalty paid to the government.

Hence, the total variable operating cost is NRs. 41,28,36,400.

Annual Operating Cost	
S.No. **Particular**	**Amount (NRs.)**
1 Fixed Operating Cost	17,11,48,000
2 Variable Operating Cost	41,28,36,400
Total	**58,39,84,400**

Thus, the annual operating cost is NRs. 58,39,84,400.

Estimation of Cost of Production

Annual Operating Cost (NRs.)	58,39,84,400
Annual Production (tons)	8,64,000
Cost of Production (NRs. Per ton)	**676**

The cost of iron ore extracted per ton is NRs. 676.

Annual Sales Realization

Sales Price (NRs. Per ton)	**1,500**
Annual Production (tons)	8,64,000
Annual Sales Realization (NRs.)	**1,29,60,00,000**

The annual sales realization of iron ore is NRs. 1,29,60,00,000.

Profitability Analysis

Cost of Production (NRs. Per ton)	676
Sale Price (NRs. Per ton)	1,500
Profit gained (NRs. Per ton)	**824**
Annual Production (tons)	8,64,000
Annual Profit (NRs.)	**71,19,36,000**

The profit gained after the sale of one ton of iron ore is NRs. 824 and the annual profit after sales of iron ore is NRs. 71,19,36,000.

Return on Investment (ROI)

Total Capital Investment (NRs.)	2,10,37,80,000
Annual Profit (NRs.)	71,19,36,000
Return on Investment (%)	**34**

The return on investment is 34% of the total capital investment.

Payback Period (PB)

Total Capital Investment (NRs.)	2,10,37,80,000
Annual Profit (NRs.)	71,19,36,000
Payback Period (Years)	**3**

The payback period is 3 years, which indicates the high profitability of the project.

4.   Conclusion

- The total iron ore reserve is estimated to be 26.053447 million tons.
- The total waste (over-burden) is estimated to be 87.5967015 million tons.
- The total fixed capital investment is NRs. 21,037.8 lakhs.
- The annual operating cost is NRs. 58,39,84,400.
- The cost of iron ore extracted per ton is NRs. 676.
- The annual sales realization of iron ore is NRs. 1,29,60,00,000.
- The profit gained after the sale of one ton of iron ore is NRs. 824 and the annual profit after sales of iron ore is NRs. 71,19,36,000.
- The return on investment is 34% of the total capital investment.
- The payback period is 3 years which indicates the high profitability of the project.

Reference

[1]   Pokharel, K. N., & Baskota, N. (Dec 2013). "*Preliminary and Follow-up Explorations of Hematite Deposit in Dhauwadi- Pokhari Area, Nawalparasi district*" Report No. 9 &10, DMG.

[2]   Adebimpe R. A., & Akande J. M. (2011). *"Engineering Economics Analysis on the production of iron ore in Nigeria"*, Geomaterials *No.1*, pp. 14-20

[3]   *"Mining Scheme of Iron Ore Deposit of Thosey in Ramechhap"* (Aug 2010).

[4]   *"Proposal for Mining License to Exploit Phulchowki Iron Ore Deposit in Lalitpur"* (Apr 2013)

[5]   *"Mine and Mineral Resource Act"*, 2042

[6]   *"Mine and Mineral Resource Regulations"*, 2042