Stochastic Open Pit Mine Production Scheduling Incorporating Price Uncertainties

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Introduction

- Mine production scheduling is an assignment problem
- Aim to maximizes profit
- No algorithm is available to solve large scale mine scheduling problem
- Number of approximate algorithms are available

Iron ore price

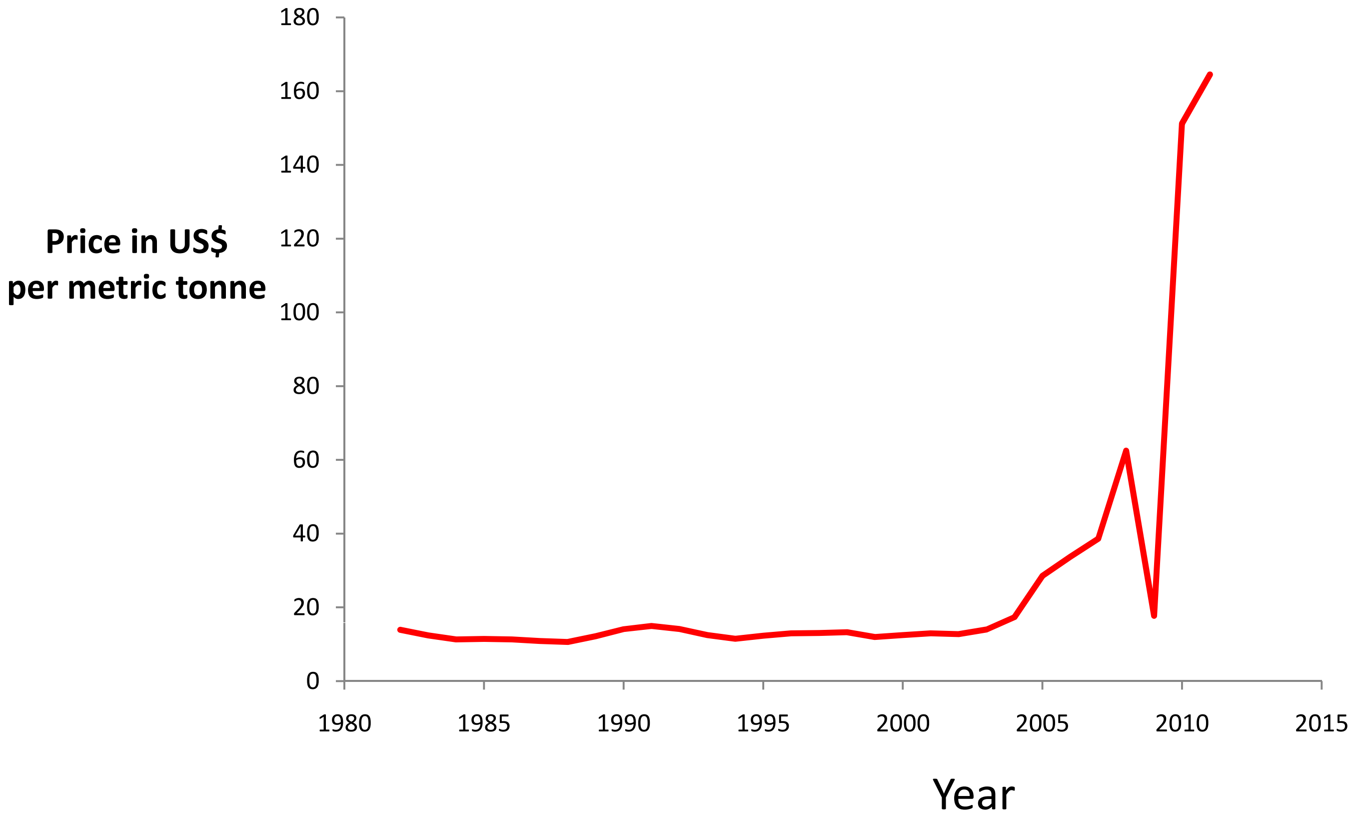


Fig: -Iron ore price chart: 1982-2011

Source: Index Mundi commodity price

www.indexmundi.com/commodities/?commodity=iron-ore&months=360

Stochastic production scheduling

$$\text{Maximize } Z = \sum_{t=1}^{T} \sum_{s=1}^{S} \sum_{i=1}^{N} \frac{c_i^{\ s}}{(1+r)^t} x_{i,t}^{\ \ s}$$

subject to

$$x^s_{\ i,t} - x^s_{\ j,t} \le 0,\ j \in \Gamma_i, i \in N, s \in S, t \in T$$

$$x^s_{\ i,t-1} - x^s_{\ i,t} \le 0,\ i \in N, s \in S, t \in T$$

$$\sum_{s=1}^{S} x^s_{i,t} = S, i \in N, s \in S, t \in T$$

$$x^s_{\ i,t} \in \{0,1\}, i \in N, s \in S, t \in T$$

$$\sum_{i=1}^{N} a^{st}_{i1} x^{st}_i \le b^{st}_1$$

$$\sum_{i=1}^{N} a^{st}_{i2} x^{st}_i \le b^{st}_2$$

Γ_i is the set of successor blocks of block i

$c^s_{\ i}$ is the economic value of block i for simulation s

N is the number of blocks in the block model

a^{st}_{i1} is the amount of ore from a block x_i of simulation s at time t

a^{st}_{i2} is the amount of waste from a block x_i of simulation s at time t

b^{st}_1 is the amount of ore production constraint from simulation s at time t

b^{st}_2 is the amount of waste production constraint from simulation s at time t

T is the total number of production periods

S is the number of simulation; r is interest rate

Constructing graph

Three simulation with economic value of blocks

c_1^1	c_2^1	c_3^1	c_4^1	c_5^1
c_6^1	c_7^1	c_8^1	c_9^1	c_{10}^1
c_{11}^1	c_{12}^1	c_{13}^1	c_{14}^1	c_{15}^1

c_1^2	c_2^2	c_3^2	c_4^2	c_5^2
c_6^2	c_7^2	c_8^2	c_9^2	c_{10}^2
c_{11}^2	c_{12}^2	c_{13}^2	c_{14}^2	c_{15}^2

c_1^3	c_2^3	c_3^3	c_4^3	c_5^3
c_6^3	c_7^3	c_8^3	c_9^3	c_{10}^3
c_{11}^3	c_{12}^3	c_{13}^3	c_{14}^3	c_{15}^3

Economic value of blocks of three simulations after multiplying λ

d_1^1	d_2^1	d_3^1	d_4^1	d_5^1
d_6^1	d_7^1	d_8^1	d_9^1	d_{10}^1
d_{11}^1	d_{12}^1	d_{13}^1	d_{14}^1	d_{15}^1

d_1^2	d_2^2	d_3^2	d_4^2	d_5^2
d_6^2	d_7^2	d_8^2	d_9^2	d_{10}^2
d_{11}^2	d_{12}^2	d_{13}^2	d_{14}^2	d_{15}^2

d_1^3	d_2^3	d_3^3	d_4^3	d_5^3
d_6^3	d_7^3	d_8^3	d_9^3	d_{10}^3
d_{11}^3	d_{12}^3	d_{13}^3	d_{14}^3	d_{15}^3

Suppose economic value of blocks are

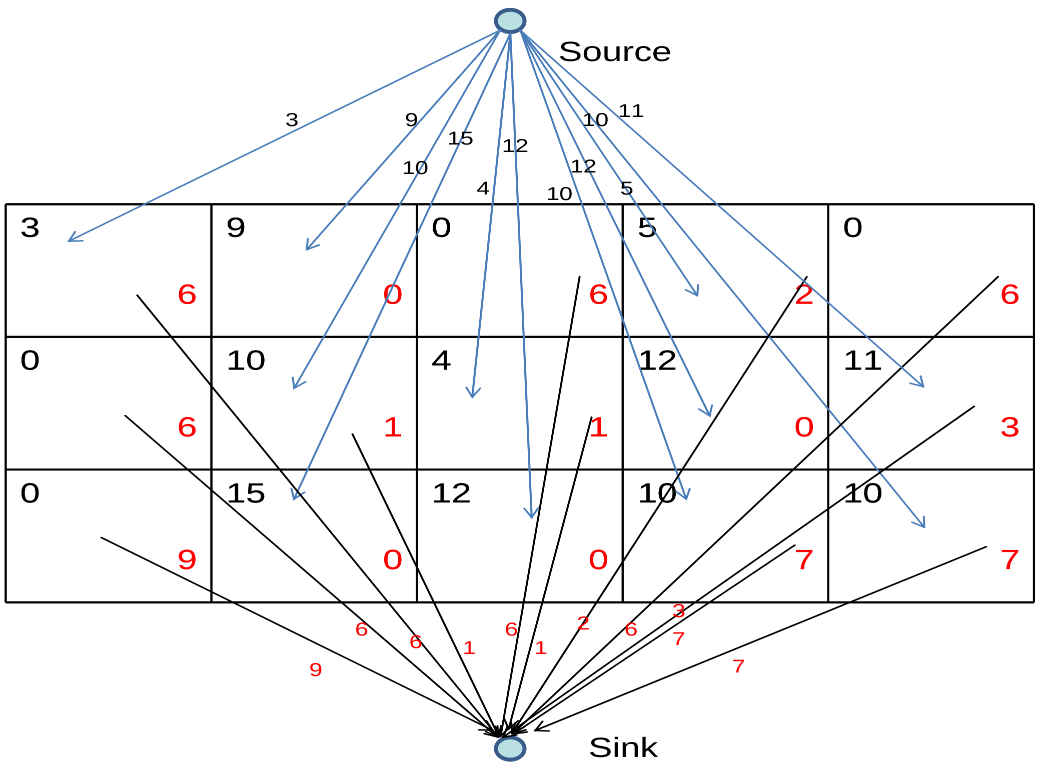
2	5	-2	2	-2
-3	6	-1	4	-2
-5	8	4	-7	-4

1	3	-1	-2	-2
-1	4	3	5	-1
-3	6	7	7	-3

-6	1	-3	3	-2
-2	-1	1	3	11
-1	1	1	3	10

Constructing graph

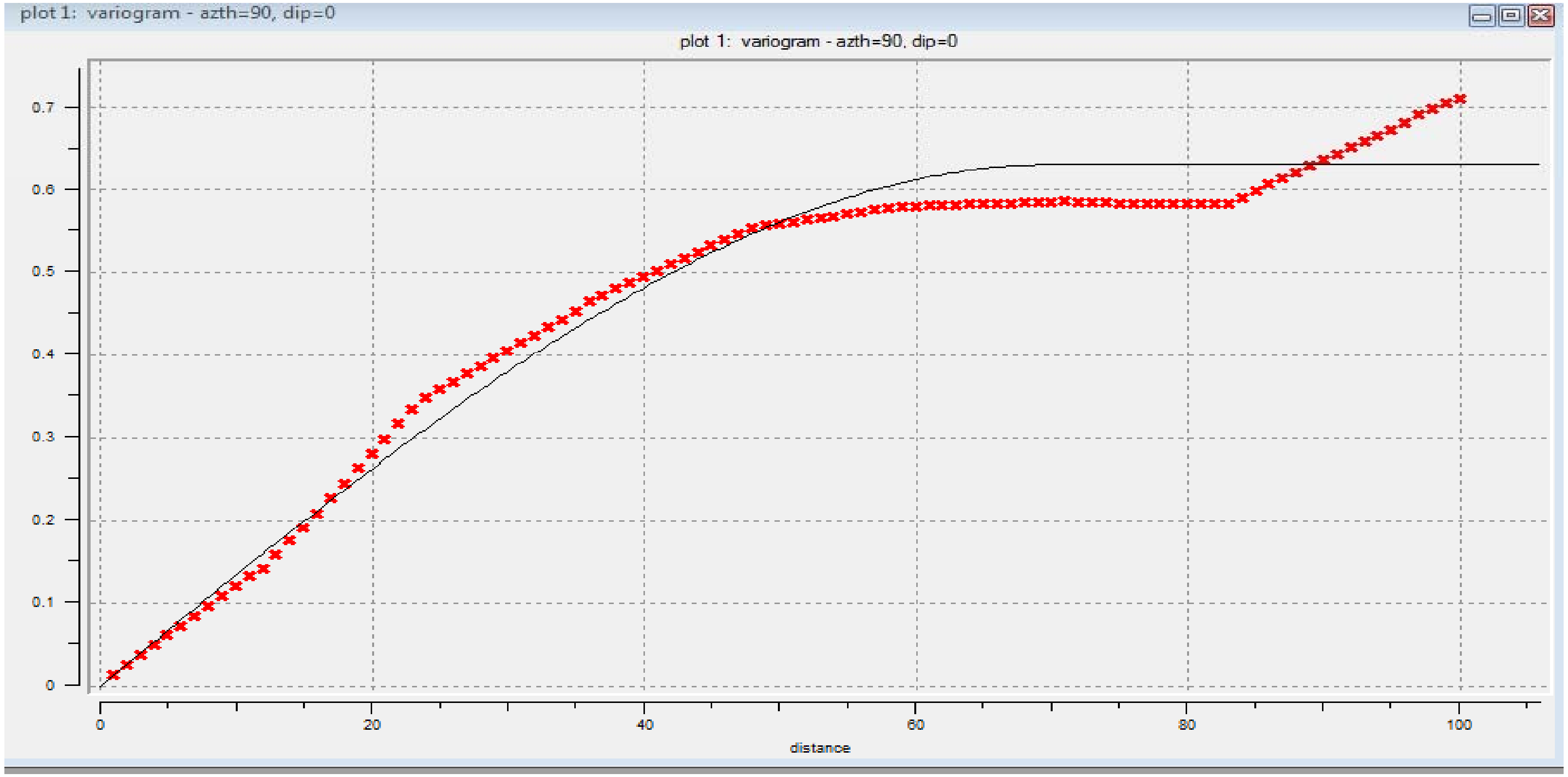
Merged graph



Case Study

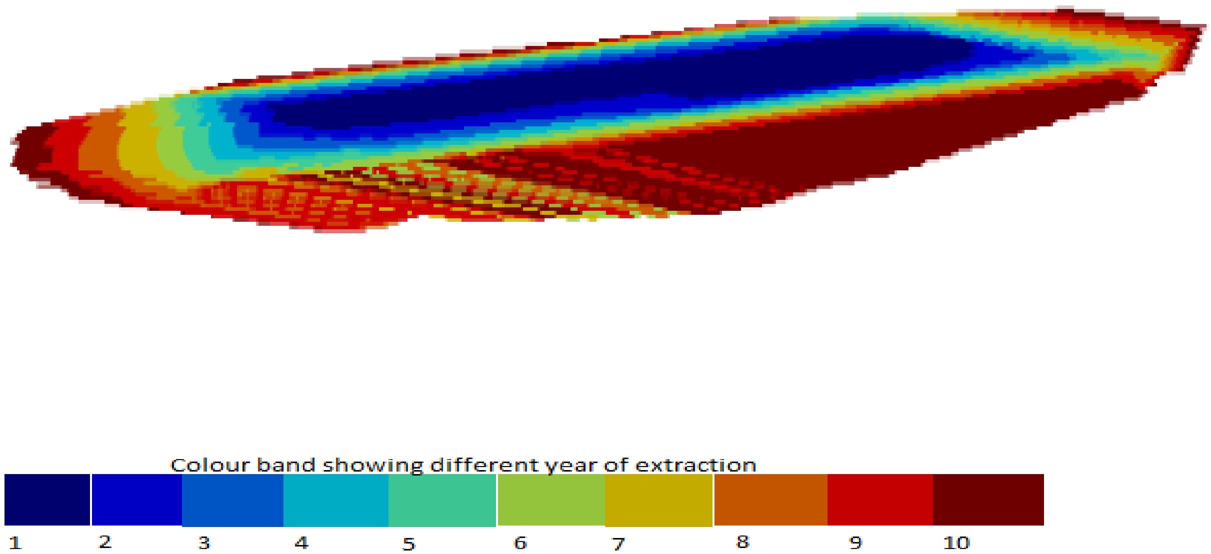
- A Iron ore deposit
- Slope angle is 45 degree
- 100 simulated ore body models
- Price simulation was done using SGS algorithm

Variogram Model



Nugget	No of structure	Sill	Type	Max	Med	Min
0	1	0.63	Spherical	100	70	27

3-D view of Pit



Conclusions

- Production scheduling was performed by incorporating price uncertainty

- The algorithm is computationally fast, so can handle large orebody model

- No ultimate pit and pushback generation is required in this algorithm

- 5% more NPV can be generated as compared to conventional method

THANK YOU