ANALYSIS OF THE TRANSPORT DISTANCES IN DEFINING THE EXPLOITATION COSTS OF DEPTH OPEN PITS OF METALS

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Abstract: In this paper is given an analysis of the transport distances for several variants of open pits for the same ore body. The basic criterion of optimization is to minimize the costs of exploitation. The analysis gives an opportunity to define the approach for determining the optimal solution - possible surface mine.

1. INTRODUCTION

One of the main conditions for the selection of optimal solution in the design of surface mines is certainly the analysis of transport distances in defining the exploitation cost especially in depth open pits. It is known that in depth open pits, exploration costs represent around 40% from the total exploitation costs.

This fact implies the need for the introduction of detailed analysis of transport distances. In this paper is used the data from the design of depth open pits.

Normally there are used only information for public character, without prejudice to the economic policy of mine.

2. EXPLOITATION COSTS RELATED TO TRANSPORT DINTANCES

Is analyzed a new designed open pit of copper, gold and silver. It is depth open pit with depth of 255 meters and 17 benches from E915 to lowest E675.

The input data are given in Table 1.

Table 1 Input data

Bench	Waste	Reserves(B+C1)							Kot
		Ore	Cu	Cu	Au	Au	Ag	Ag	
	t	t	t	%	kg	g/t	kg	g/t	
915	112139	12050	95.09	0.789	3.71	0.31	1.51	0.13	9.31
900	1318583	14007	21.68	0.155	2.92	0.21	1.44	0.10	94.14
885	3598147	89020	90.15	0.101	2.70	0.03	1.23	0.01	40.42
870	6289007	145100	145.52	0.100	37.22	0.26	78.65	0.54	43.34
855	8089482	323000	545.91	0.169	85.47	0.26	313.66	0.97	25.04
840	7674662	700515	1594.24	0.228	306.42	0.44	503.43	0.72	10.96
825	6324665	1067000	2721.78	0.255	372.48	0.35	790.67	0.74	5.93
810	5083154	1273000	3525.69	0.277	526.51	0.41	919.63	0.72	3.99
795	4064807	1420100	3397.43	0.239	490.85	0.35	1239.52	0.87	2.86
780	3003098	1603550	4396.72	0.274	597.26	0.37	1697.64	1.06	1.87
765	1997468	1710040	3982.25	0.233	530.00	0.31	1330.91	0.78	1.17
750	1080337	1920500	4998.03	0.260	656.15	0.34	1808.30	0.94	0.56
735	630976	1701205	4236.41	0.249	703.53	0.41	1752.40	1.03	0.37
720	427989	1215980	2993.69	0.246	548.77	0.45	1343.18	1.10	0.35
705	293457	805020	2740.18	0.340	394.68	0.49	1124.33	1.40	0.36
690	77619	634010	1844.55	0.291	299.28	0.47	779.69	1.23	0.12
675	38364	239015	503.48	0.211	91.48	0.38	565.09	2.36	0.16
Σ	**50103954**	**14873112**	**37832.78**		**5649.44**		**14251.28**		
Average				**0.254**		**0.38**		**0.96**	**3.37**

According to the presented input data, it can be concluded that it is a polymetalic deposit of copper, gold and silver, with a given amount of development of open pit at 15 meters, identical with the possible bench height.
In addition, the average content of cooper is 0254%, gold 0.38 g / t, silver, 0.96 g / t.
According to the basic geometry, it is a depth open pit, with a total depth of 255 meters, with an average ratio of overburden 3.37.

3. ANALYSIS OF TRANSPORT COSTS

The transport distance are calculated from the open pit model, and we get following values:

Table 2 Transport distance

Bench	Transport distance		Waste x distance Cumulative, t km	Ore x distance cumulative, t km	Cumulative t km
	Waste	Ore			
	km	km			
915	1.1	1.75	123353	21088	144441
900	1.273	2.023	1801909	49424	1851333
885	1.466	2.181	7076793	243576	7320370

870	1.641	2.361	17397054	586157	17983211
855	1.812	2.53	32055195	1403347	33458543
840	1.989	2.707	47320097	3299641	50619739
825	2.168	2.858	61031971	6349127	67381098
810	2.321	3.032	72829972	10208863	83038835
795	2.508	3.192	83024507	14741823	97766329
780	2.706	3.357	91150891	20124940	111275831
765	2.882	3.551	96907593	26197292	123104885
750	3.08	3.724	100235030	33349234	133584264
735	3.263	3.901	102293906	39985635	142279541
720	3.43	4.066	103761908	44929809	148691717
705	3.599	4.219	104818060	48326189	153144249
690	3.788	4.415	105112079	51125343	156237422
675	3.952	4.59	105263695	52222422	157486117
Σ			**105263695**	**52222422**	**157486117**
Average	**2.10**	**3.51**			

Costs for transport distance are calculated according to the length of road transport of ore and waste. It is made an analyses for each bench separately.

Table 3 Costs calculating for transport distance

Bench	Waste x distance €/(t km)	Ore x distance €/(t km)	Suma €/(t km)	Suma Cumulutive €/(t km)
915	48107.68	11598.13	59705.80	59705.80
900	654636.94	15584.89	670221.83	729927.63
885	2057204.82	106783.94	2163988.76	2893916.39
870	4024901.48	188419.61	4213321.09	7107237.47
855	5716675.30	449454.50	6166129.80	13273367.27
840	5953311.72	1042961.76	6996273.48	20269640.75
825	5347630.74	1677217.30	7024848.04	27294488.79
810	4601220.32	2122854.80	6724075.12	34018563.91
795	3975868.56	2493127.56	6468996.12	40487560.03
780	3169289.86	2960714.54	6130004.40	46617564.43
765	2245113.82	3339793.62	5584907.44	52202471.87
750	1297700.50	3933568.10	5231268.60	57433740.47
735	802961.68	3650020.39	4452982.07	61886722.54
720	572520.52	2719296.07	3291816.59	65178539.13
705	411899.46	1868008.66	2279908.12	67458447.25
690	114667.52	1539534.78	1654202.30	69112649.55
675	59130.06	603393.37	662523.43	69775172.98
Σ	**41052840.97**	**28722332.01**	**69775172.98**	**69775172.98**

If we calculated the costs for transport distance separately for cooper, gold and silver we get values independently when mine will be exploited only for one kind of metal in depth. Below are two tables of costs for metal copper, gold, silver and monometal copper independently.

The costs calculation for cooper exploitation is made on the basis of transport distances only in cooper exploitation. So, in the calculation were taken only cost exploitation of copper, other quantities of gold and silver are neglected or are calculated as waste.

Table 4 Cost calculating for Cu exploitation

Bench	**Cu cumulative t**	**Cost for 1 t Cu in open pit**		
		the bench €/t	**cumulative €/t**	**cumulative US$/t**
915	95.09	627.89	627.89	828.81
900	116.77	6251.13	6251.13	8251.49
885	206.92	13985.86	13985.86	18461.34
870	352.44	20165.76	20165.76	26618.80
855	898.35	11295.22	14775.33	19503.43
840	2492.59	4388.47	8131.97	10734.20
825	5214.36	2580.98	5234.48	6909.52
810	8740.05	1907.17	3892.26	5137.78
795	12137.48	1904.09	3335.75	4403.19
780	16534.20	1394.22	2819.46	3721.69
765	20516.44	1402.45	2544.42	3358.64
750	25514.47	1046.67	2251.03	2971.35
735	29750.88	1051.12	2080.16	2745.82
720	32744.57	1099.59	1990.51	2627.48
705	35484.75	832.03	1901.05	2509.39
690	37329.30	896.80	1851.43	2443.89
675	37832.78	1315.90	1844.30	2434.48
Σ	**37832.78**		**1844.30**	**2434.48**

The costs calculation for gold exploitation is made on the basis of transport distances only in gold exploitation. So, in the calculation were taken only cost exploitation of copper, other quantities of cooper and silver are neglected or are calculated as waste.

Table 5 Cost calculating for Au exploitation

Bench	**Au cumulative kg**	**Cost for 1 kg Au in open pit**		
		the bench €/kg	**cumulative €/kg**	**cumulative US$/kg**

915	3.71	16106.61	16106.61	21260.72
900	6.62	110190.42	110190.42	145451.35
885	9.33	310267.24	310267.24	409552.75
870	46.55	152683.61	152683.61	201542.36
855	132.02	72143.83	100541.53	132714.82
840	438.44	22831.94	46230.90	61024.79
825	810.92	18859.85	33658.68	44429.45
810	1337.43	12770.94	25435.71	33575.13
795	1828.28	13179.17	22145.12	29231.56
780	2425.55	10263.48	19219.40	25369.61
765	2955.54	10537.66	17662.57	23314.59
750	3611.69	7972.68	15902.17	20990.87
735	4315.23	6329.45	14341.48	18930.75
720	4864.00	5998.48	13400.19	17688.25
705	5258.68	5776.55	12828.01	16932.97
690	5557.96	5527.32	12434.89	16414.06
675	5649.44	7242.49	12350.81	16303.08
Σ	**5649.44**		**12350.81**	**16303.08**

The costs calculation for silver exploitation is made on the basis of transport distances only in silver exploitation. So, in the calculation were taken only cost exploitation of copper, other quantities of cooper and gold are neglected or are calculated as waste.

Table 6 Cost calculating for Ag exploitation

Bench	**Ag cumulative kg**	**Cost for 1 kg Ag in open pit**		
		the bench €/kg	**cumulative €/kg**	**cumulative US$/kg**
915	1.51	39486.75	39486.75	52122.51
900	2.95	247676.17	247676.17	326932.54
885	4.17	693531.99	693531.99	915462.23
870	82.82	85811.96	85811.96	113271.79
855	396.48	19658.89	33478.07	44191.06
840	899.91	13897.24	22524.11	29731.83
825	1690.57	8884.73	16145.10	21311.54
810	2610.21	7311.70	13032.91	17203.44
795	3849.73	5218.95	10517.00	13882.44
780	5547.36	3610.91	8403.56	11092.69
765	6878.27	4196.30	7589.47	10018.10
750	8686.58	2892.92	6611.78	8727.55
735	10438.98	2541.07	5928.43	7825.52
720	11782.16	2450.76	5531.97	7302.20
705	12906.49	2027.79	5226.71	6899.25
690	13686.18	2121.60	5049.81	6665.75

675	14251.28	1172.41	4896.06	6462.80
Σ	**14251.28**		**4896.06**	**6462.80**

The analysis is performed at the monometal copper. For this purpose, are used the adopted values of the prices of metals from table 7.

Table 7 Calculating costs for monometal Cu exploitation

Bench	**Monometal of Cu**			**Cost of 1 t Cu in open pit**		
			cumulative	**The bench**	**cumulative**	**cumulative**
	t	**%**	**t**	**€/t**	**€/t**	**US$/t**
915	115.06	0.95	115.06	518.90	518.90	684.95
900	37.43	0.27	152.49	19502.13	4786.74	6318.50
885	104.73	0.12	257.22	27632.41	11250.81	14851.06
870	354.53	0.24	611.74	20047.17	11617.99	15335.74
855	1043.57	0.32	1655.31	5908.71	8018.66	10584.63
840	3295.63	0.47	4950.94	2122.89	4094.10	5404.21
825	4813.74	0.45	9764.68	1459.33	2795.23	3689.70
810	6456.38	0.51	16221.06	1041.46	2097.19	2768.28
795	6180.56	0.44	22401.62	1046.67	1807.35	2385.70
780	7808.47	0.49	30210.10	785.05	1543.11	2036.91
765	6986.34	0.41	37196.44	799.40	1403.43	1852.52
750	8738.60	0.46	45935.04	598.64	1250.33	1650.43
735	8222.24	0.48	54157.28	541.58	1142.72	1508.39
720	6099.58	0.50	60256.86	539.68	1081.68	1427.82
705	4995.07	0.62	65251.93	456.43	1033.82	1364.64
690	3544.66	0.56	68796.59	466.67	1004.59	1326.06
675	1066.70	0.45	69863.29	621.10	998.74	1318.34
Σ	**69863.29**	**0.47**	**69863.29**		**998.74**	**1318.34**

Values of metals and the ratio € / US $ in the calculation are taken from the following Table 8. The analysis was made with average prices of metals in the last 3 years.
Normally, the change in stock prices of metals have great impact on the definition of total cost of exploitation. Therefore, you should pay particular attention to selecting and determining the same.

Table 8 Metal prices

Metal prices		
Cu	7500	US$/t
Au	40000	US$/kg

Ag	1000	US$/kg
€	1.32	US$

After the calculation of transport distances is made a diagram of the dependencies of the transport distance of the total cost of exploitation of one ton of copper or 1 ton of monometal copper for the particular model of depth open pit metal.

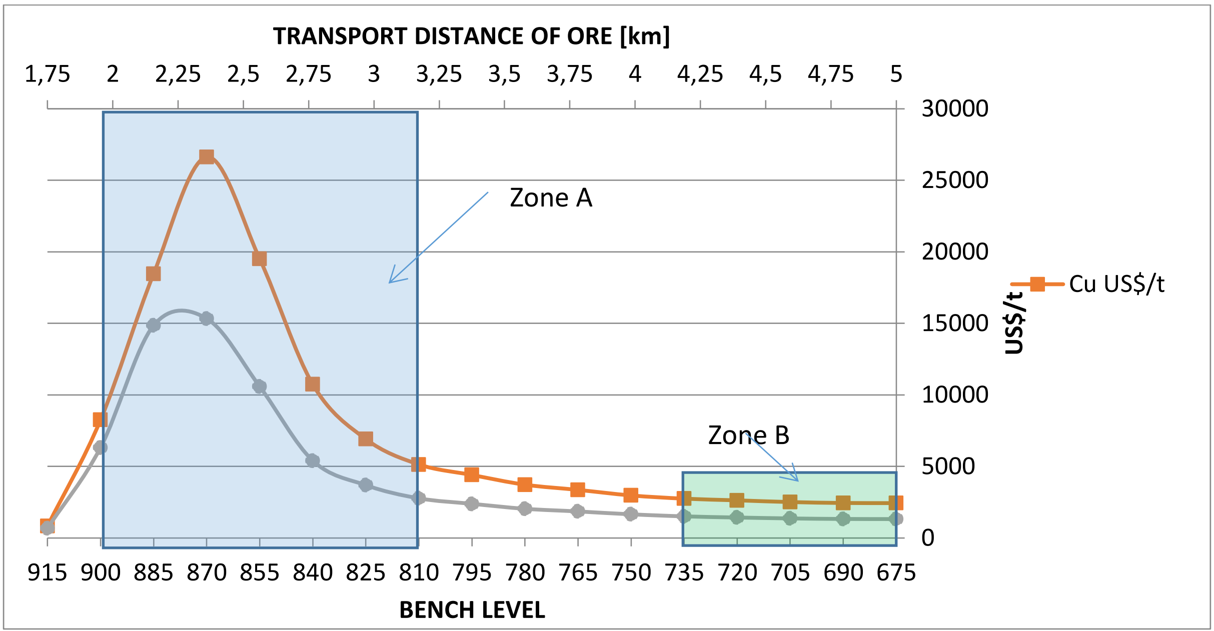

Fig. 1 Price cost dependance of cooper exploitation at transport distance

According to the analysis of transport distances (see diagram in Fig. 1), we can conclude the following:

- ✓ The least favorable is area A, where there is a major change in the value of the price of the cost of cooper exploitation (and copper monometal) in function of the deepening of the surface mine or transport distances. With a little change of the transport distance from 1.75 to 3.1 km, ie with enhancement from E900 to E810, comes a change in the cost price of 1 ton exploitation of copper from 5000 till 24000 US $.
- ✓ The most favorable is zone B, where there is negligible change in the value of the cost of cooper exploration (monometal copper) in function of the deepening of the surface mine or an increase in the transport of ore. The change of the transport distances from 4.25 to 5 km, a causing minimal changes in the price of the exploitation costs of 1 ton of copper from 1300 to 1600 US $. With that is possible an enhancement of surface mine from E735 to E660.
- ✓ The rest of the surface mine covered between zones A and B, is possible exploitation only under conditions of controlled costs for exploitation: without big jumps in stock prices of metals, the cost of equipment (which is relatively stable) and the cost of labor.

CONCLUSION

Given depending on transport distances and costs of exploitation of depth open pits of metals provides an opportunity to make strategic decisions in mines management in order to find the optimum solutions with minimum cost.
In fact, it is necessary for each new and existing open pit to develop a model, where from transport solution will define the true value of the cost of exploitation of useful mineral resource - in this case the metals copper, gold and silver. Logically, polymetalic useful mineral resource is converted at the monometal.

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