

## Analysis of Delays in Hard Rock Mine Lateral Development: A Case Study

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**Abstract:** The aim of this study is to identify and isolate the major causes of delays in underground lateral development at AngloGold Ashanti (AGA), Obuasi Mine, Ghana. It uses fishbone analysis to identify and present 20 possible causes of delays in lateral development at the mine. By employing Pareto analysis, 7 major causes of delays have been isolated. They are: scoop problems, low compressed air, labour shortages, bad ground, flood, power outages and waste pass getting full. The study concludes that, should management concentrate in minimising the 7 major causes of delays, it will be solving about 80% of the problems associated with delays in underground lateral development at AGA, Obuasi mine. The study further gives specific recommendations to reduce delays in lateral development at the mine.

**Key words:** Delays, Fishbone analysis, lateral development, Pareto analysis, underground mining

### INTRODUCTION

Edu (2000) defines lateral development as any system of development in thick orebodies in which headings are driven horizontally across the orebody and connected to main haulage drifts, entries, or shafts. The primary purposes are for exploring the orebody and for preparing the orebody for final exploitation. As a result of the important roles these two activities play in mine productivity, there is the need to establish an optimal rate of advancement with the barest minimum amount of delays. According to Serguei *et al.* (2007), some of the effects of delays on lateral development include: increase in operating costs; increase in time required to get to the orebody thus affecting economic parameters such as rate of return, net present value and payback period; and slower exploration of new targets among others. This study therefore seeks to identify and organize the known or possible causes of delays in lateral development at Anglo Gold Ashanti Obuasi Mine; isolate the major causes of delays in lateral development at the mine; and recommend ways of reducing these delays.

### MATERIALS AND METHODS

**Brief profile of study area:** AngloGold Ashanti Ltd (AGA) was formed in 2004 by the merger of AngloGold (with headquarters in South Africa) and Ashanti Goldfields Corporation (with headquarters in Ghana). AngloGold Ashanti Limited is now a global gold producer with 21 operations in four continents. The company is listed on the New York, Johannesburg, Accra, London and Australian stock exchanges, as well as the Paris and

Brussels bourses (Wikipedia, 2010a). AGA operates two mines in Ghana; AGA Obuasi, predominantly underground and AGA, Iduapriem Mine, an open pit mine in Tarkwa.

**Geographical and geological elements:** The Obuasi municipal district is located at the southern part of the Ashanti Region of Ghana. It covers a land area of 1624 km<sup>2</sup>. It has Obuasi as its Administrative Capital where the famous and rich Obuasi Gold Mine, now AngloGold Ashanti is located (Wikipedia, 2010b). Obuasi is about 56 km south of Kumasi, the Ashanti Regional Capital and the second largest city in Ghana, and 200 km North west of Accra, the nation's capital.

The municipality has a rather undulating topography and the climate is of the semi-equatorial type with a double rainfall regime. Mean annual rainfall ranges between 1250 and 1750 mm. Mean average annual temperature is 25.5°C and relative humidity is 75-80%. The vegetation is predominantly a degraded and semi-deciduous forest. The forest consists of limited species of hardwood which are harvested as lumber. The municipality has nice scenery due to the hilly nature of the environment as exemplified in Fig. 1.

Obuasi gold deposits are part of a prominent gold belt of Proterozoic (Birimian) volcano-sedimentary and igneous formations which extend for a distance of approximately 300 km in a north-east/south-west trend in south-western Ghana. Obuasi mineralization is shear-zone related and there are three main structural trends hosting gold mineralization: Obuasi, Gyabunsu and Binsere trends (Leube *et al.*, 1990). Quartz veins and sulphide ores constitute the two types of ore mined at Obuasi.



Fig. 1: Overview of the Obuasi Gold Mine, Ghana (Mining-Technology.Com, 2006)



Fig. 2: Typical lateral development at level 41 (MiningTechnology.Com, 2006)

**Mining practices:** The Obuasi mine has worked surface and underground mineralisation but mining is now mainly underground, extending to depths of 1600 m. The mainly flat-back, cut-and-fill stopes used to exploit several ore blocks have been converted to mechanised open stopes. There are 15 shafts but the main hoisting shafts are George Cappendell, Kwesi Mensah, Kwesi Renner and Sansu. The shafts are linked by an electric rail haulage system serving six dump stations on the 41 level (Fig. 2). Designed by Nordic Mining Technology, this system comprises two eight-car trains of 14 m<sup>3</sup> side dumping cars, hauled by 15 t locomotives supplied by British manufacturer Clayton. The dump stations are fed by belt conveyors from ore passes to the haulage level (Mining-Technology.Com, 2006). The mine practices the normal drill and blast methods of exploiting the ore underground. Mining and Building Contractors, (MBC) is the contracting company that is tasked with developing all the laterals for AGA.

**Development cycle activities:** At AGA, development is said to have commenced when the development layouts are ready and it is said to have ended when all services are extended to the workface for a new round to commence. The activities involved in the development cycle are as outlined in Fig. 3.

The cycle begins by marking the face with lime paint or spray to indicate the spots to be drilled. Drilling is done with a conventional manually operated drilling machine. AGA operates in a typical 4 m × 4 m dimension drive. Drilling starts with a 1.2 m rod, continues with a 1.8 m rod, and then ends with a 2.4 m rod. The average break advance is 90% which gives an average rate of advance per blast of 2.2 m. Blastholes are drilled at a diameter of 38 mm and reamed holes have diameter of about 57 mm. AGA employs different types of drill patterns and varies them from round to round with varying number of blastholes. A typical diamond and square pattern can take about 56 holes per round.

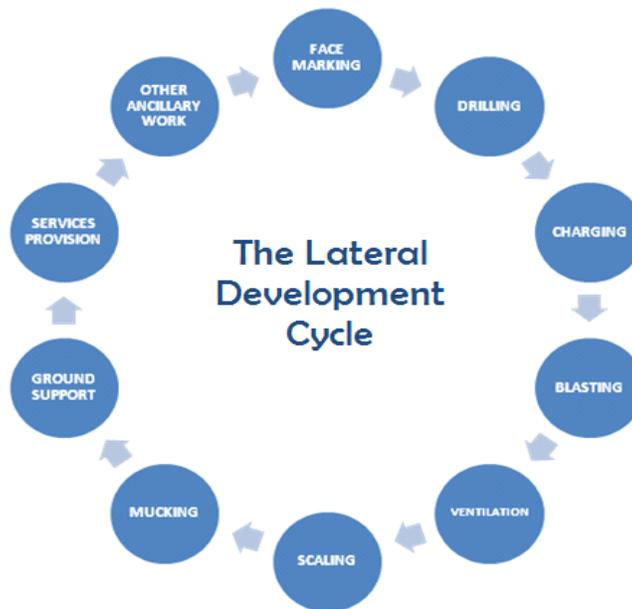


Fig. 3: Lateral development cycle at AGA Obuasi mine

After drilling is over the crew then make preparation for charging. To avoid any contamination of explosives which could otherwise cause misfires, the drill holes are cleaned and flushed thoroughly with compressed air. Charging is done with the aid of ANFO loader or the blasthole charger. The cap fuses are inserted at the bottom of the drill holes and the ANFO loader pumps the ANFO at high pressure into the holes. Delay elements are also used to enable sequential blasting. Blasting is done at the end of every shift.

After a blast the area is ventilated. The period between the time of start of ventilation and the time to get back to the blasted area is referred to as the re-entry period and usually ranges from a minimum of 45 min to a maximum of 60 min. After the re-entry period, the face cannot be accessed until all hanging rocks are scaled down by the leader of the blasting crew. The provision of water blasts also helps to submerge the dust and fumes at the face.

Mucking is the next stage after scaling. At this stage the loading equipment such as Wagner scooptrams comes to collect the broken materials and tram to a distance to dump. At longer distances (500 m and beyond), scooptrams, dump trucks and underground locomotives are combined. This process is repeated until all the broken rocks are removed from the face. Muck bays are developed every 50 m. At Kwesi Mensah shaft (KMS) where the study was conducted, the main mucking equipment were scooptrams and underground locomotives.

Ground support is usually dependent on the geology of the area. In competent rocks, ground support is not very much a problem but in weak grounds, wire mesh screens, rock bolts, cable bolts and concrete are employed.

Once there is enough ground support, essential utilities such as ventilation fans, compressed air, water, electricity, lighting and other ancillary works are undertaken so as to prepare the face for the next round.

**Model formulation:** Figure 4 presents a model that outlines the processes of field studies for data collection and analysis. The data on delays collected on the various activities in the lateral development cycle at AGA, Obuasi are input into MS Excel. Excel functions and tools are then employed to conduct the fishbone and Pareto analyses.

**Method of data collection:** At AGA, blasting is done at the end of every shift during lateral development, hence any activity that hinders the smooth operation of the cycle is considered as a cause of delay in the productivity of lateral development in the mine. Field studies were therefore conducted to identify those activities in the lateral development cycle that result in calling off blasting (blast lost) at the Kwesi Mensah Shaft (KMS) section of AngloGold Ashanti, Obuasi Mine, Ghana in 2009. The effects of such causes were then measured by the number of blast lost in the various shifts which culminated into blast lost per month data for the period of the study.

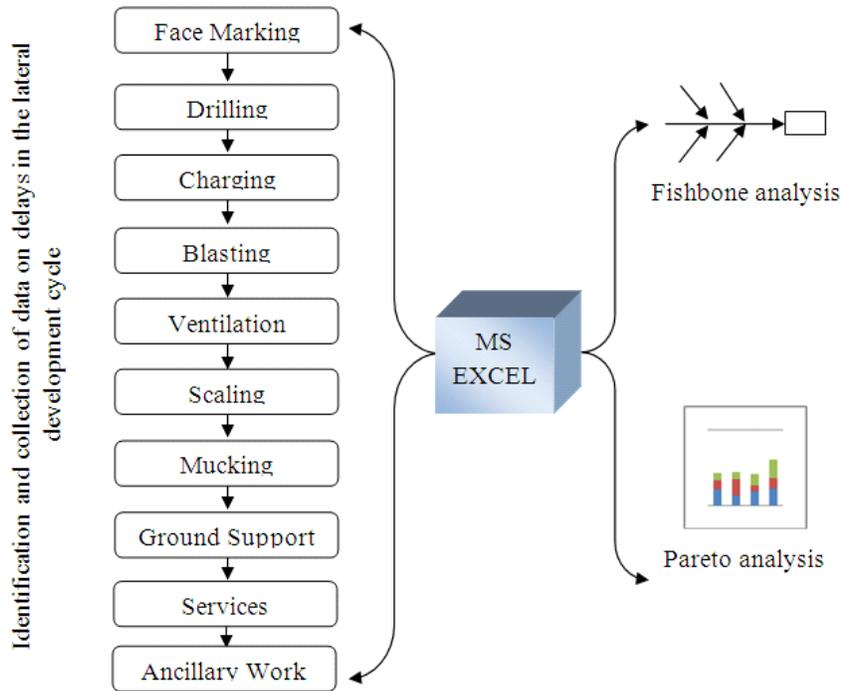


Fig. 4: Schematic diagram of the model formulation process

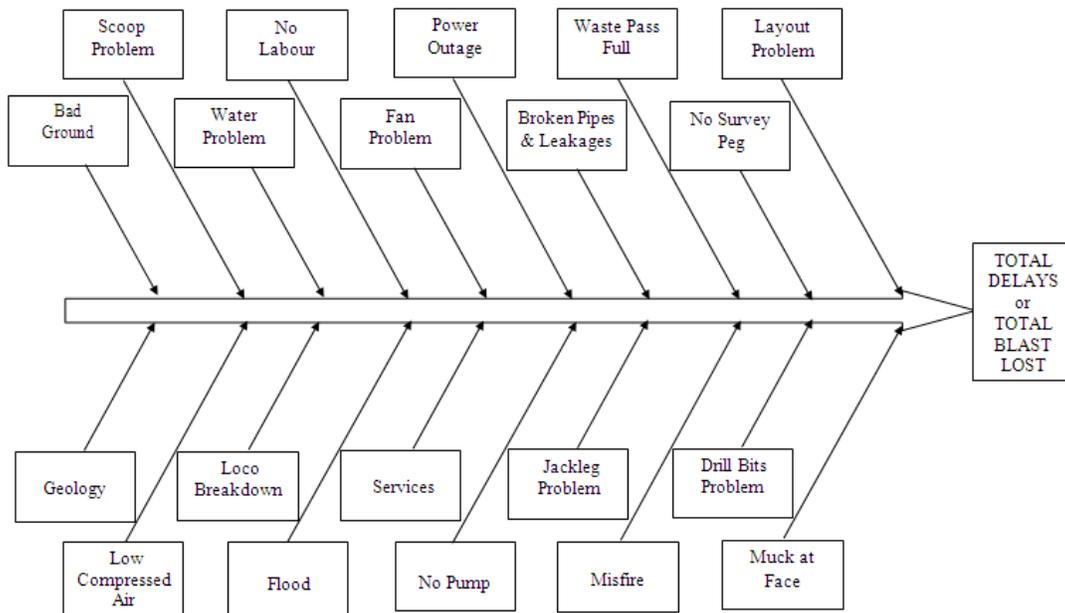


Fig. 5: Fishbone analysis of possible causes of delays in the lateral development cycle at AGA

## RESULTS AND DISCUSSION

**Fishbone analysis:** A Cause-and-Effect Diagram is a tool that helps identify, sort, and display possible causes of a

specific problem or quality characteristic. It graphically illustrates the relationship between a given outcome and all the factors that influence the outcome. This type of diagram is sometimes called an "Ishikawa diagram"

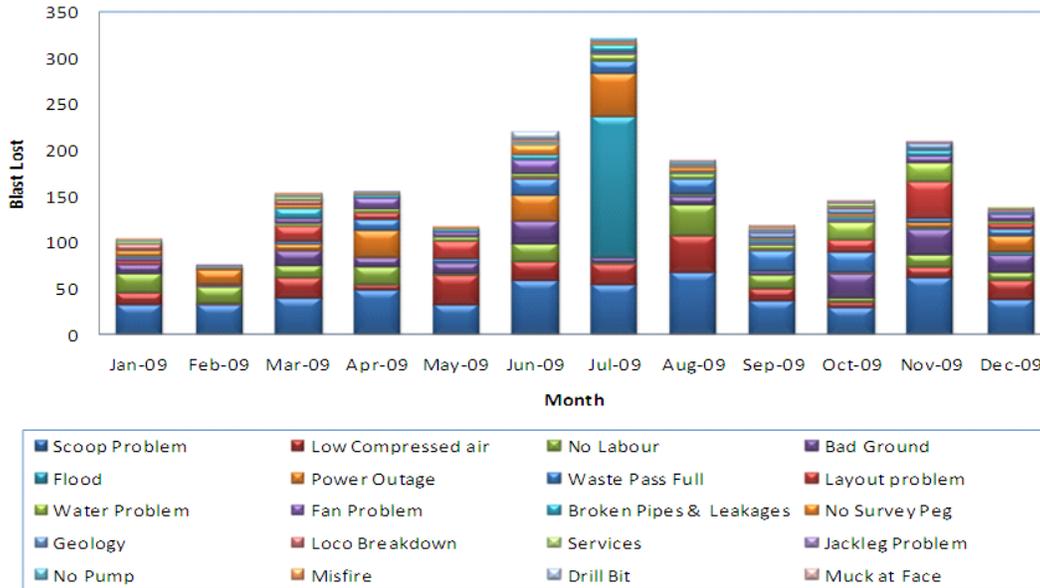


Fig. 6: Number of blast lost due to delays in lateral development at AGA

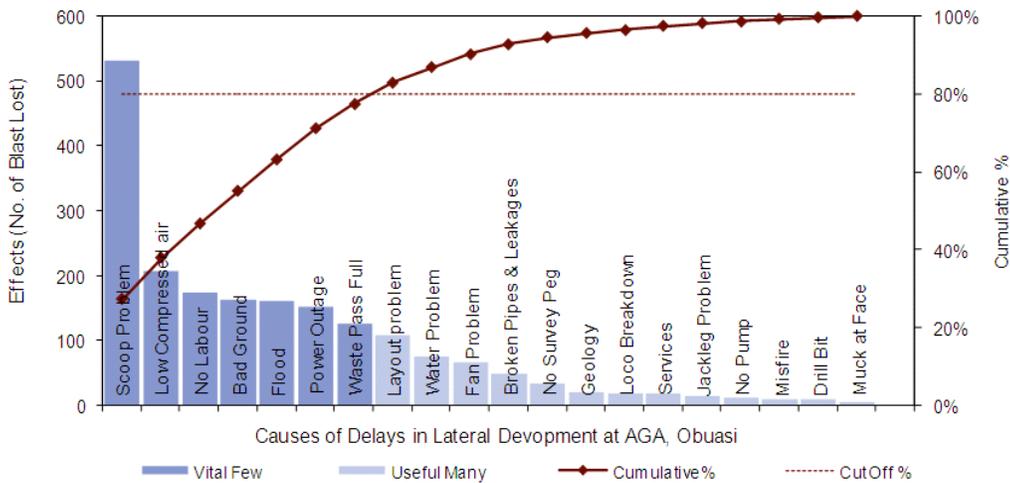


Fig. 7: Pareto analysis to isolate major causes of delays in lateral development at AGA

because it was invented by Kaoru Ishikawa, or a "fishbone diagram" because of the way it looks (BSC, 1996). In this study, the effects or outcome is the total delays represented by the total number of blast lost per month in lateral development at AGA, Obuasi. The causes are identified as: unavailability of loading unit (scooptram); low compressed air; unavailability of specialised labour for the activities of the lateral development cycle such as drilling, blasting and machine operation; bad ground; flooding; power outages; waste pass getting full; layout problems; water problems; fan malfunctioning; broken pipes and leakages; unavailability

of survey peg for direction; geological features such as the type of formation, faults and joints; breakdown of haulage unit (locomotives); inadequate provision of services; problems with drilling equipment (jackleg); unavailability of pump; misfire; problems with drill bits; and having muck material still occupying a face. The result of the fishbone analysis is as shown in Fig. 5.

**The Pareto analysis:** Pareto analysis is a statistical technique in decision making that is used for the selection of a limited number of tasks that produce significant overall effect. It uses the Pareto Principle (also know as

Table 1: Number of Blasts Lost Due to Delays in Lateral Development at AGA

Month Cause	Jan 09	Feb 09	Mar 09	Apr 09	May 09	Jun 09	Jul 09	Aug 09	Sep 09	Oct 09	Nov 09	Dec 09	Total
Scoop problem	33	33	39	48	33	59	54	67	37	29	62	38	532
Low compressed air	12	1	22	6	31	20	23	40	13	6	11	21	206
No Labour	21	18	14	20	2	20	1	34	15	5	14	9	173
Bad ground	10	2	16	10	12	24	6	9	4	26	27	18	164
Flood 0	0	0	0	0	0	153	2	0	0	2	4	161	
Power outage	0	16	7	29	0	28	46	1	0	2	6	17	152
Waste pass full	0	0	4	12	4	18	14	16	22	22	5	8	125
Layout problem	4	2	16	7	19	2	0	0	1	13	39	5	108
Water problem	0	0	3	4	5	4	7	6	5	19	20	3	76
Fan problem	3	0	5	12	5	15	3	1	3	3	8	8	66
Broken pipes and leakages	2	1	11	4	4	5	8	1	3	3	6	1	49
No survey peg	6	0	4	0	1	11	3	4	2	3	0	0	34
Geology	0	0	0	0	0	0	0	0	5	5	8	2	20
Loco breakdown	7	0	5	1	0	0	0	2	0	2	0	2	19
Services	4	1	4	2	0	0	0	1	0	4	0	2	18
Jackleg problem	0	2	1	1	0	0	1	1	3	3	1	0	13
No Pump	1	0	1	0	0	2	3	3	2	0	0	0	12
Misfire	1	0	2	0	1	3	0	0	2	0	0	0	9
Drill bits	0	0	0	0	0	9	0	0	0	0	0	0	9
Muck at face	0	0	0	0	0	0	0	2	2	1	1	0	6
Total	104	76	154	156	117	220	322	190	119	146	210	138	1952

Table 2: Causes of delays and their cumulative effects

#	Main causes	Effects (No of blast lost/Yr)	Relative effect (%)	Cumulative (%)
1	Scoop problem	532	27.25	27.25
2	Low compressed air	206	10.55	37.81
3	No labour	173	8.86	46.67
4	Bad ground	164	8.40	55.07
5	Flood	161	8.25	63.32
6	Power outage	152	7.79	71.11
7	Waste pass full	125	6.40	77.51
8	Layout problem	108	5.53	83.04
9	Water problem	76	3.89	86.94
10	Fan problem	66	3.38	90.32
11	Broken pipes & leakages	49	2.51	92.83
12	No survey peg	34	1.74	94.57
13	Geology	20	1.02	95.59
14	Loco breakdown	19	0.97	96.57
15	Services	18	0.92	97.49
16	Jackleg problem	13	0.67	98.16
17	No pump	12	0.61	98.77
18	Misfire	9	0.46	99.23
19	Drill bits	9	0.46	99.69
20	Muck at face	6	0.31	100.00

the 80/20 rule) the idea that by doing 20% of the work you can generate 80% of the benefit of doing the whole job. Or in terms of quality improvement, a large majority of problems (80%) are produced by a few key causes (20%). This is also known as the vital few and the trivial many (Duncan, 2008). This section applies this principle to identify the major causes of delays leading to the total delays at the end of each month for the period of the study. Table 1 presents the data on the number of blasts lost as a result of the twenty (20) causes of delays during lateral development at AGA Obuasi Mine in the year 2009. A visual impression is shown in Fig. 6.

The Pareto analysis revealed that about 80% of the delays were caused by seven (7) out of the twenty (20) identified delays (Table 2 and Fig. 7). These were identified as scoop problem, low compressed air, no labour, bad ground, flood, power outage, waste pass full.

The implication of the Pareto analysis is that, if management concentrate efforts at reducing delays attributed to the seven (7) major causes of delays, the mine would be solving 80% of the problem associated with blast lost and hence productivity in lateral development on the mine.

### CONCLUSION

Lateral development plays a very vital role in the total productivity of a mine hence the need to make sure delays are minimised in all its activities. Some delays are avoidable and others are not. However, a fore knowledge on the causes of delays can help management put in measures to limit these delays and hence increase productivity. This study has analysed the causes of delays in underground lateral development at AngloGold

Ashanti, Obuasi Mine using Fishbone analysis and Pareto analysis. Out of the 20 possible causes of delays identified through the Fishbone analysis, the Pareto analysis isolated 7 major causes of delays which management should concentrate in minimising, to solve about 80% of the problems associated with delays in underground lateral development at AGA Obuasi mine. The 7 major causes of delays are scoop problem, low compressed air, no labour, bad ground, flood, power outage and waste pass full.

### RECOMMENDATIONS

The following recommendations may be considered:

- Spares should be made available at all times with good maintenance to reduce scoop and compressed air problems.
- The optimal temperature required for a machine to operate should be observed to avoid excessive temperatures causing damage to machine parts like hoses.
- Qualified personnel should be involved in the purchasing of machines and other inputs to avoid buying inferior products that cannot serve its full life. Purchasing should also be done from a reputable company which will provide very good warranty.
- Mine roads should be kept in good shape at all time as this frequently causes damage to machine tyres.
- Machine operators must be educated on the consequences of equipment abuse while measures are put in place to sanction anyone caught in the act.
- Detailed job analysis should be conducted to know the number of workers to assign a particular job so as to avoid too many men or too few men to any job.
- Workers should be motivated to work willingly and enthusiastically towards the achievement of company targets.
- The geology of the area must be studied critically before drilling and blasting are done.
- Backup power plants should be readily available to power the compressed air and other utilities required as soon as there are power outages.
- The heavy flood that occurred in July was an exceptional case and must be avoided. Sumps, pumps and drainage systems must be carefully maintained.

### ACKNOWLEDGMENT

The authors are very grateful to Mr Kofi Frimpong-Ofofu, a Mining Engineering graduate of the University of Mines and Technology, Tarkwa Ghana; Mr. Stanley Mensa and Mr. Bashir Ahmed all of AngloGold Ashanti Obuasi Mine, Ghana.

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