Managing Delays in Open Pit Shovel-Truck Systems – A Case Study

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Abstract

Delays are frequently encountered on a daily basis in open pit shovel-truck operations. A greater portion of these delays which are avoidable or reducible to the barest minimum if well managed can significantly reduce shovel-truck cycle times and increase utilisation. The traditional approach to analyzing delay data is by frequency plots categorized by type of delay and does not present the data in a format which facilitates management of the delays. This paper uses log dispersion plotting approach to analyse delay data from open pit shovel truck operations at Goldfields Ghana Ltd., Tarkwa Mine. Delay types were categorised into delay codes to determine which ones were acute, chronic or a combination of both. The delay codes which were critical to the reduction of delays and improvement of shovel-truck utilization were prioritised.

1 Introduction

Shovel-truck operations continue to be the most popular form of material handling systems in surface mining since they often offer many operational advantages. In an open pit operation the trucks move from the shovels to the dump/crusher and back. Sometimes they go to the repair shop or to the fuelling station; they regularly go to the places for driver exchange and meals. Occasionally the trucks have to wait at a shovel, at the dump-crusher, at the repair shop or at the fuelling station when there already is a truck being loaded at the shovel or being fuelled or when all positions at the dump-crusher or all bays at the repair shop are occupied. These situations are caused by variability of the loading, dumping, repair, and fuelling times and of the time intervals between trucks arriving at these facilities (Ramani, 1990). Delays therefore affect a shovel-truck system and their efficient management have a direct impact on productivity.

Delays can be classified as fixed or variable. Fixed delays are predictable as to time of occurrence and duration such as shift change, equipment inspection, breaks, refuelling, blasting, etc. Fixed delays usually are not considered in truck cycle time. Variable delays are not predictable as to time of occurrence and duration. Variable delays include delays for haulage road maintenance, loading area cleanup, operator relief stop, loading oversize rock, preparing of muck pile for better digging, idling shovel, waiting trucks, tramming (propelling of equipment), late start of shift, early closure of shift, breakdown of equipment, bogging of shovel or truck, etc., and are considered in the truck cycle time (Hays, 1990).

The common approach used in analysis of delay data is to plot histograms categorised by delay code. Log dispersion plots have been proposed for the analysis of unplanned equipment downtimes; this method allows unplanned equipment breakdown data to be analysed in a format which facilitates decision making (Temeng and Eshun, 2009; Knights, 1999). This approach could also be used to analyse delay data since it would offer similar advantage. This paper presents an analysis of delay data of a fleet of dump trucks and shovels from Goldfields Ghana Limited, Tarkwa gold mine (GFGL) using log dispersion plot.

2 Shovel-Truck System at Goldfields Ghana Ltd., Tarkwa

The GFGL is located in south-western Ghana, about 300 km by road west of Accra, the capital, at latitude 5°15' N and longitude 2°00' W. It is situated some 4 km west of the town of Tarkwa with good access roads and an established infrastructure. It is served by a main road connecting to the port of Takoradi some 60 km to the southeast on the Atlantic coast (Anon., 2008a).

GFGL practices owner mining and conducts its operations using conventional open pit mining methods. Mining is carried out two shifts per day in seven pits. Six metre benches are mined in three metre flitches. The loading and hauling operations of GFGL comprise of 44 diesel powered Caterpillar 785C dump trucks of 144 tonne capacity and 13 hydraulic excavators. The excavators comprise of four Liebherr 984C's, four Liebherr 994B's, three Terex RH120E's, a Liebherr 994-200 and a Liebherr 9150. Shovel-truck operations are controlled by a fully automated dispatching system.

3 Data Collection and Analysis

Field visits were conducted to observe various delays in the shovel truck operations. Delay data for one production month was extracted from the dispatching system of GFGL. The dispatching system included; the code assigned to each type of delay, its status message, frequency and duration in hours. The same types of delay were identified for the fleet; the corresponding duration and frequency recorded. The data was then categorised into delay types. A total of 17 delay types were recorded and for each type the length of time (in hours) and its frequency were recorded in MS Excel for the fleet. A total of 3379.9 hours of scheduled hours for the fleet went into delays. To facilitate analysis the delay types were categorised into delay codes. Table 1 presents a description of the various delay codes. To facilitate further analysis of the data the mean time for each event and percentage of total duration for each delay code was determined. A summary of this is presented in Table 2.

Table 1 Description of Fleet Delay Codes

Delay Type	Description	Delay Code
Bogged	When the excavator gets stuck in soft material.	A
Geologist	Wait for a geologist to determine were to mine since selective mining is what is practised.	B
Operator Relief Stop	Time used by the operator to relieve himself.	C
Lighting Plant	Time to remove the lighting plant from mining face during day shift or to bring it back during night shift to facilitate mining.	D
No Dozer	When there is no bulldozer for floor preparation and the excavator has to wait.	E
Road Construction	The delay that occurs as result of road construction in the pit.	F
Battering	Time used by the excavator for battering of pit walls	G
Coffee Break	Time above allotted time (15 minutes) for coffee break during the night shift	H
Fuelling Shovel	Time above allotted time (30 minutes) for fuelling a shovel	I
Blasting	Time above allotted time (30 minutes) for blasting	J
Fuelling Truck	Time above allotted time (20 minutes) for fuelling trucks	K
Lunch Break	Time above allotted time (30 minutes) for lunch break by operators	L
Floor Preparation	Dozer work on the pit floor in order to make it motorable and prevent damage to dump truck tyres	M
Shift Change	Time above allotted time (30 minutes) for shift change by operators	N
Tramming	Propulsion of the excavator from one bench to another (usually in the same pit or to a different pit) after the completion of excavation or to another portion of the same bench	O
Queue	When at least one truck is waiting to be loaded at the excavator	P
Hanging Excavator	Waiting time of the excavator for trucks to arrive for loading	Q

Table 2 Summary of Delay Data

Delays code	Frequency	Duration (h)	Mean (h)	% Frequency	% Mean	% Duration
A	1	0.12	0.12	0.01	1.03	0.004
B	4	0.32	0.08	0.05	0.69	0.009
C	23	2.81	0.12	0.28	1.05	0.083
D	17	3.08	0.18	0.21	1.56	0.091
E	11	6.45	0.59	0.14	5.05	0.191
F	2	7	3.50	0.02	30.15	0.207
G	6	12.59	2.10	0.07	18.08	0.372
H	110	15.12	0.14	1.36	1.18	0.447
I	50	26.72	0.53	0.62	4.60	0.791
J	111	60.45	0.54	1.37	4.69	1.789
K	148	68.16	0.46	1.82	3.97	2.017
L	177	76.41	0.43	2.18	3.72	2.261
M	1558	153.09	0.10	19.20	0.85	4.529
N	622	363.22	0.58	7.67	5.03	10.746
O	2209	444.1	0.20	27.23	1.73	13.139
P	2319	1037.32	0.45	28.58	3.85	30.691
Q	745	1102.94	1.48	9.18	12.75	32.632
TOTAL	8113	3379.90	11.61	100	100	100

4 The Log Dispersion Plotting Method

Delay is the product of two factors: the frequency of delay in a particular delay code and its associated duration. The log dispersion plotting method enables the delays to be classified into whether they are acute (large durations), chronic (excessive delay frequency) or a combination of both. The plot provides a detailed representation of the delay patterns in the fleet, facilitating diagnosis in the root cause of the delays.

To obtain a log dispersion plot, the total duration of a delay code, in this case, i, is considered as Cost_i which is given as (Temeng and Eshun, 2009; Knights, 1999):

$$\mathrm{Cost}_{\mathrm{i}} = n_i \times Mean_i \qquad (1)$$

Where, n_i is the frequency associated with code i and Mean_i is the mean time of delay code i.

Taking the logarithm of Equation 1 becomes:

$$\log(\mathrm{Cost}_{\mathrm{i}}) = \log(n_i) + \log(Mean_i) \qquad (2)$$

A log dispersion plot is a graph of log (Mean_i) against log (n_i). From the log dispersion plot, delays with large mean times (Mean_i) are considered as acute problems. Those delay codes with high frequency of occurrence (n_i) are considered as chronic problems and those delay codes with large mean and high frequency of occurrence are both acute and chronic problems. The log dispersion plot can be partitioned into four quadrants if threshold values for the mean and n are determined. The upper quadrants represent acute delays, the right hand quadrants represent chronic delays, and hence, the upper right hand quadrant represents a region of acute and chronic delays (Temeng and Eshun, 2009; Knights, 1999). The lower left hand quadrant is the quadrant with neither acute nor chronic delays. This constitutes the least problematic quadrant for delays in terms of the frequency and the mean.

4.1 Determination of Threshold Values

Threshold values can either be absolute values, determined by company policy, or relative values which depend on the relative magnitudes and the quantity of the delay data (Temeng and Eshun, 2009; Knights, 1999). One approach for determining the threshold values based on the magnitude and quantity of delay data is presented.

The total duration, D, is given by:

$$D=\sum d_i \tag{3}$$

where d_i is the duration due to delay code i. The total frequency, N, is given by:

$$N=\sum n_i \tag{4}$$

If Q is the number of distinct delay codes used to categorise the delay data, the threshold limit for acute delays ($\text{Limit}_{\text{Mean}}$) can be defined as:

$$\text{Limit}_{\text{Mean}} = \frac{D}{N} \tag{5}$$

and the threshold limit for chronic delays (Limit_{n}) can be defined as:

$$\text{Limit}_{\text{n}} = \frac{N}{Q} \tag{6}$$

5 Results and Analysis

Fig. 1 is a log dispersion plot of the delay data of the fleet based on Table 2 and Equation 2. To determine the threshold values, figures from Table 2 were substituted in Equations 3 to 6. From Table 2, D = 3379.9 hours, N = 8113 and Q = 17. Therefore, the threshold limit value for acute delays ($\text{Limit}_{\text{Mean}}$) is 3379.9/8113 = 0.42 hours and that for chronic delays (Limit_{n}) is 8113/17 = 477. These threshold values were used to divide the log dispersion plot into four quadrants as shown in Fig. 1.

A frequency plot of delays is also presented in Fig. 2. Table 3, which was extracted from Fig. 1, shows the various delays which are chronic, acute, or acute and chronic.

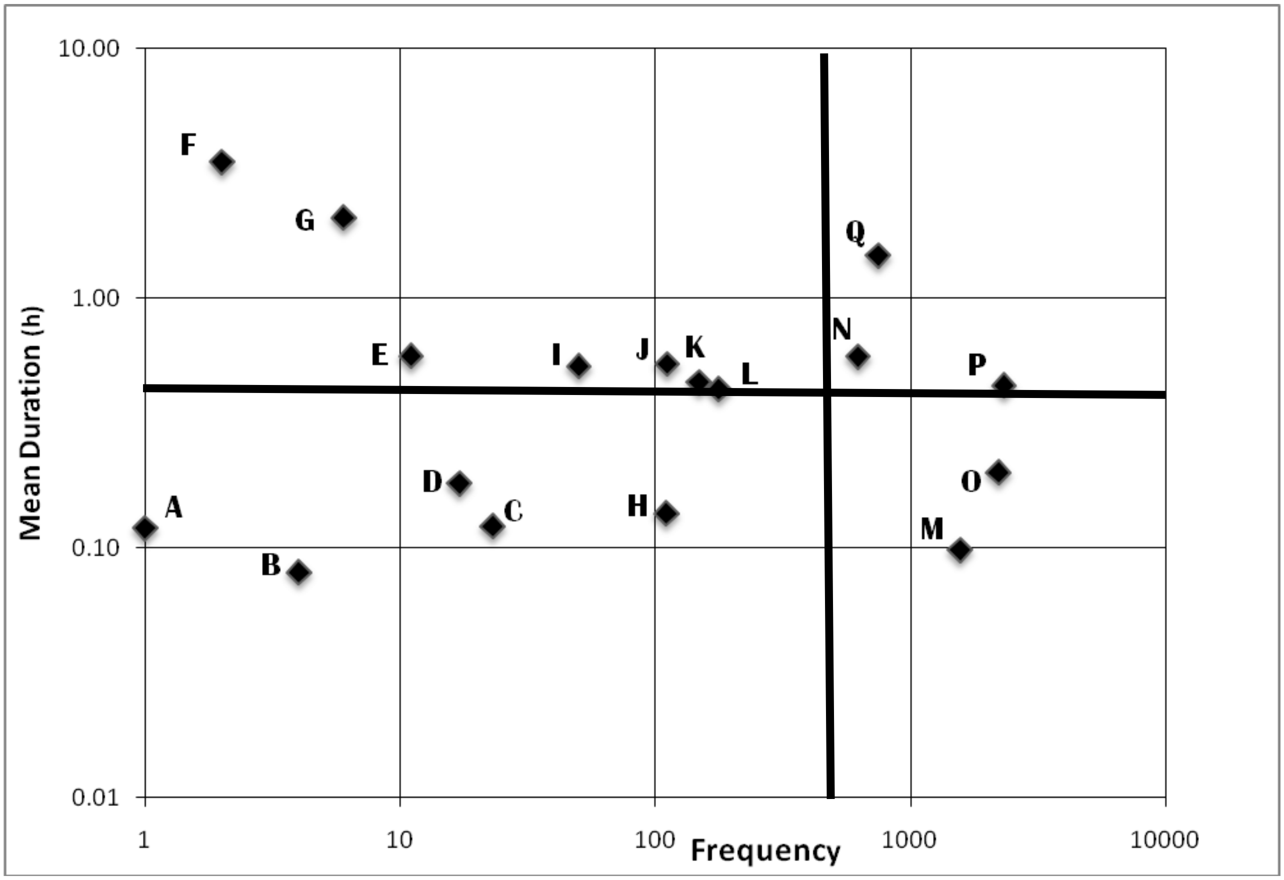

Fig. 1 Log Dispersion Plot of Delay Data

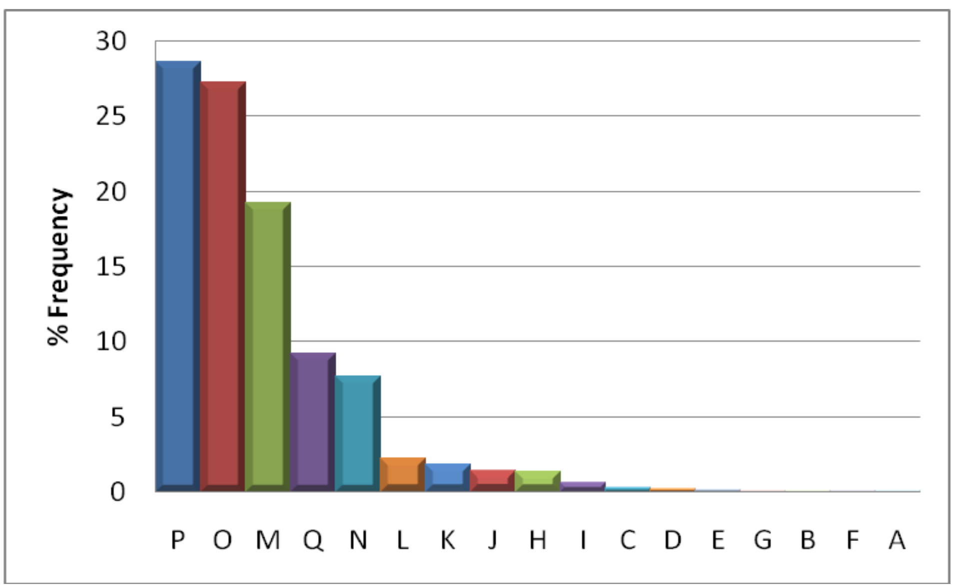

Fig. 2 Histogram of Delays Prioritised by Frequency

Table 3 Delay Categories Based on Log Dispersion Plot

Delay Code	Category	Frequency	Duration (h)	Mean (h)	% Frequency	% Mean	% Duration
Acute and Chronic Delays							
N	Shift Change	622	363.22	0.58	7.67	5.03	10.746
P	Queue	2319	1037.32	0.45	28.58	3.85	30.691
Q	Hanging Excavator	745	1102.94	1.48	9.18	12.75	32.632
SUB TOTAL		**3686**	**2503.48**	**2.51**	**45.43**	**21.63**	**74.069**
Acute							
F	Road Construction	2	7	3.50	0.02	30.15	0.207
G	Battering	6	12.59	2.10	0.07	18.08	0.372
E	No Dozer	11	6.45	0.59	0.14	5.05	0.191
I	Fuelling Shovel	50	26.72	0.53	0.62	4.60	0.791
J	Blasting	111	60.45	0.54	1.37	4.69	1.789
K	Fuelling Truck	148	68.16	0.46	1.82	3.97	2.017
L	Lunch Break	177	76.41	0.43	2.18	3.72	2.261
SUB TOTAL		**505**	**257.78**	**8.15**	**6.22**	**70.26**	**7.628**
Chronic							
M	Floor Preparation	1558	153.09	0.10	19.20	0.85	4.529
O	Tramming	2209	444.1	0.20	27.23	1.73	13.139
SUB TOTAL		**3767**	**597.19**	**0.30**	**46.43**	**2.58**	**17.668**
Other Delays							
A	Bogged	1	0.12	0.12	0.01	1.03	0.004
B	Geologist	4	0.32	0.08	0.05	0.69	0.009
C	Operator Relief Stop	23	2.81	0.12	0.28	1.05	0.083
D	Lighting Plant	17	3.08	0.18	0.21	1.56	0.091
H	Coffee Break	110	15.12	0.14	1.36	1.18	0.447
SUB TOTAL		**155**	**21.45**	**0.64**	**1.91**	**5.51**	**0.634**
GRAND TOTAL		8113	3379.9				

The chronic delays are floor preparation and tramming; these are the most frequently occurring. Floor preparation can be associated with the nature and fragmentation of the material being mined; larger, harder material requiring frequent dozer activity. The acute delays are road construction, battering, no dozer, fuelling shovel, blasting, fuelling truck and lunch break. The acute and chronic delays are shift change, queuing and the hanging excavator. Queuing and the hanging excavator are normally associated with inefficiencies of operator, dispatcher or equipment.

The delays in the acute and, acute and chronic quadrants offer the best opportunity for reduction in delay time, since they constitute the highest set of mean duration of occurrence. With reference to Table 3, the 10 delay codes in the acute and, acute and chronic category, shift change, queue, hanging excavator, road construction, battering, no dozer, fuelling shovel, blasting, fuelling truck and lunch break constitute 92% of the total mean duration. The chronic delays which constitute 2.6% of the mean and 17.7% of the duration should be given second priority attention.

Once the various delays are prioritised, the next step is to identify their root causes, identify measures to reduce the duration or reduce the frequency of delay in order to increase productivity. Determining the root cause of delays requires the combined effort of both experienced production and operating personnel. Root cause of delays could be analysed under areas like; man, method, environment, material and machine problems. Following the determination of the root causes for each delay the necessary action could be taken to minimise the duration and frequency of occurrence.

6 Conclusions

A Log dispersion plot has been used to analyse the delays of a fleet of 44 dump trucks and 13 shovels. The delay codes in the acute and, acute and chronic categories were found to be the ones that contributed most to the total duration of the delays and therefore should be given the highest priority in minimising the delays; chronic delays should be given the second priority. Reduction in delays associated with shift change, queue, hanging excavator, road construction, battering, no dozer, fuelling shovel, blasting, fuelling truck and lunch break is the most critical to a significant improvement in productivity.

The successful application of log dispersion plots to analyse delay data is dependent on the availability of sufficient delay data of good quality. In spite of the cost (in terms of time and money) of recording and storing such data, such analysis to improve on the productivity of equipment will justify the investment.

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