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Abstract. The large mining companies usually outsource the blasting service. There are two options regarding the management of the stocks of the explosives: first, the mining company management; second using Vendor Managed Inventory [VMI], which means that the supplier responsible for the management of the stock and all the logistics of delivery of the material. The present work has the objective of studying the effectiveness of this VMI in a supplier of a transnational mining company. Logistics costs are accounted for the period from January to September 2018. They are compared to the cost that the miner would have if the material requests were made on their account. The VMI in this mining company is very effective with a total saving of BRL 676.801,92 concerning logistics and BRL 7,356,295.36 about inventories. Furthermore, it was identified that there was no supply disruption, the stocks were in equilibrium according to the maximum and minimum limits and there was a low obsolescence percentage of products.

Keywords: Cost reduction · Logistics · Freight · Inventory · Explosive · Production Management

1 Introduction

Mining is an important activity in modern life whose objective is the extraction of minerals of interest for various purposes [1]. From smartphones to autonomous cars, from the structures in civil construction to the money we use, ores are the basis for a multitude of essential items for everyday life. Most of the mineral extractions use explosives of different types for the fragmentation and dismantling of the rock in the production process [2].

One of the main challenges in large mining companies is to manage the inventory of the explosives used to carry out the rock dismantling. The control

and management of explosives stock is an essential activity because the lack of material or the non-compliance with any of the conditions of the army, the body office that regulates and supervises the use of this type of product, can impact on all activities subsequent to dismantling and in mining can cause losses in the order of millions.

Inventory management and planning are matters of extreme importance in a business environment once the investment is a substantial part of an organization's operating budget. In Supply Chain Management one of the most important issues is the inventory management [3]. Managing stocks economically consists essentially in the search for rationality and balance with consumption, in such a way that: the effective needs of its consumers are met with minimum cost and the lowest possible risk of shortages [4].

Mining companies are aware of the importance of explosives inventory management and their correct application usually outsource this type of service, that is, they hire a company to supply the explosives and/or carry out the dismantling and control the inventories.

When mining companies hire the rock dismantling service, there are two options regarding inventory management, the first option is the mining company itself to do all the inventory management by making its own explosive orders according to its demand. The second option is to leave the entire inventory management to the supplier (Supplier Managed Inventory) where the supplier plans orders according to the monthly demand informed by the customer.

According to Freitas et al. [5] the Vendor Managed Inventory (VMI), which assigns a company the task of managing the stock of the sequential link in its production chain, determining when and how much of each product should be sent to its immediate customer, one of the most discussed collaborative practices for improving the efficiency of the supply chain. The idea revolves around the manufacturer directly manages the inventory at the client [6].

Inventory management by the supplier - VMI, according to Santos and Alves [7] has been used to minimize inventories, without reducing the service level. It is an inventory initiative managed by supplier, where he assumes responsibility for planning and managing the customer's inventory, based on an agreed replacement service contract.

This study aims to assess the effectiveness of inventory management carried out by an explosive supplier in a large multinational in the mining industry.

2 Methodology

As mentioned previously, the objective of the study is to investigate the effectiveness of the VMI to manage inventory in a large mining company. The VMI optimize supply chain performance since the supplier has access to the customer's inventory data being responsible for maintaining the inventory level required by the customer [8]. To do so, the vendor through regularly scheduled reviews of the on-site inventory to counter and restocked to predefined levels [8].

The VMI system will be evaluated in this study from the perspective of two main points: (1) logistics costs; and (2) costs with a mobilized inventory.

The mining company has three units located in Para state, north of Brazil: S11D, Sossego and Carajás. The supplier responsible for the VMI is established in Paraná, south region of Brazil.

The products are manufactured and shipped to the three subsidiaries, based on the mining demand and stock availability. Therefore, logistics and inventory management is a hard activity and requires very effective planning.

To analyse logistics costs, the expenses in escort and freight during the period from January to September 2018 were collected. After, we predicted the theoretical values of escort and freight implementing the VMI, and calculate the differences regarding the real values.

The costs of mobilized inventory were calculated based on how much is spent in BRL (Brazilian Reis) to maintain inventories at the end of each month about 4 types of explosive: Initiators, Cord, Reinforcers and Wrapped.

3 Results

Table 1 presents the stock at the end of each month, from January to September, of the four categories of explosives: Initiator, Cord, Reinforcer and Wrapped.

Table 1: Stock of explosives

Month	Initiator (parts)	Cord (m)	Reinforcer (pars)	Wrapped (kg)
January	12,525	61,135	4,258	13,100
February	13,187	50,511	4,879	6,600
March	13,199	41,362	3,710	4,100
April	12,673	30,543	2,022	2,975
May	11,170	33,552	2,319	8,075
June	13,883	65,251	8,520	13,775
July	10,792	43,786	5,998	12,975
August	12,301	17,572	3,752	4,900
September	12,238	65,239	2,756	10,375
Maximum Storage	18,250	100,000	11,500	16,300
Minimum Storage	9,000	20,000	2,000	3,000

The maximum stock of explosives is established by the Brazilian Army's while the minimum is agreed between the supplier and the mining company. Therefore, occurs a disruption due to lead time and consumption of the products.

During the period of this study, there was the consumption of 24,985 initiators as can be seen in Table 2. Moreover, 110 initiators are discarded by obsolescence which represents 0.44% of the total.

Table 2: Month consumption

Month	Initiator (parts)	Cord (m)	Reinforcer (pars)	Wrapped (kg)
January	2,197	48,090	3,010	3,516
February	1,858	51,124	3,471	9,500
March	2,148	52,899	3,759	6,500
April	1,966	55,819	3,768	9,125
May	3,705	65,741	5,043	8,900
June	2,669	54,301	3,674	9,900
July	4,099	71,465	4,072	14,800
August	2,831	66,214	4,836	14,075
September	3,512	57,333	4,004	14,125
Total	24,985	522,986	35,637	90,441

Analyzing the required amount of transportation that would be required to meet the units, Table 3 shows the total of trips that would be required was reduced from 77 to 54 trips while Table 4 presents sharing cargo of the plants in Brazilian Reais (BRL).

Table 3: Number of trips

Month	Amount Required			Freight Total		Diference
	Plant Sossego	Plant Carajás	Plant S11D	Required(No sharing)	Used (Sharing)	
January	3	4	1	8	5	3
February	4	2	3	9	5	4
March	2	2	2	6	3	3
April	2	4	3	9	6	3
May	3	2	3	8	5	3
June	2	4	2	8	6	2
July	4	4	2	10	9	1
August	2	5	3	10	9	1
September	3	4	2	9	6	3
Total	77	77	77	77	54	23

Table 5 shows the value predicted in BRL with the stock of explosives. The stock was used as a basis at the end of each month and multiplied by the average price of each of them and reached the actual value in the period.

The budgeted value was calculated by the mining company considering the amount necessary to maintain the deposit with its maximum capacity of each

Table 4: Cost and freight

Month	Total Required (no sharing)	Total Used (sharing)	Diference
January	135,818.64	84,886.65	50,931.99
February	152,795.67	84,886.65	67,909.02
March	101,863.98	50,931.99	50,931.99
April	152,795.97	101,863.98	50,931.99
May	135,818.64	84,886.65	50,931.99
June	135,818.64	101,863.98	33,954.66
July	169,773.30	152,795.97	16,977.33
August	169,773.30	152,795.97	16,977.33
September	152,795.97	101,863.98	50,931.99
Total	1,307,254.11	916,775.82	390,478.29

Table 5: Real versus budget

Item	Real	Budget
Initiator	4,938,908.48	7,245,067.50
Cord	2,650,002.48	5,832,000.00
Reinforcer	826,186.68	2,237,670.00
Wrapped	502,762.50	959,418.00
Total	8,917,860.14	16,274,155.50

material, therefore the maximum capacity value of each item is multiplied by the respective average price.

Making a general analysis the [VMI] presents a cost reduction for the mining company with logistics of BRL 676,801.12 and with inventories of BRL 7,356,295.36.

4 Final Remarks

Supplier Managed Inventory - VMI in an explosive supplier company to a multinational mining company is effective in showing considerable savings in both logistics and capital mobilized in stock in relation to the option of traditional inventory management. On the other hand requires special attention in relation to cargo sharing because the greater the amount of loads the greater the cost reduction with freight and escorts and also management should be attentive to keep stocks at levels avoiding mobilising high amounts of capital without need.

It is noticeable that the [VMI] allows a balance of inventories within the maximum and minimum limits and there was no disruption of supply something that is extremely critical for this branch of activity. Efficient management by the supplier allows a minimum disposal of products by obsolescence presenting a small financial impact to the customer.

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