Cost modelling of the product mix from mining operations using the activity-based costing approach

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Abstract

This work adds the Activity-Based Costing Approach in mining operations with a product mix. After analyzing and collecting data from an aggregate mine located in Brazil, a cost model was built, and from that, a cost management and analysis methodology of a mine in operation is created. This work has the innovation advantages of using ABC as a tool for planning the operation of the mine, identifying the more profitable products. At the end, it is concluded that the creation of a cost model to be used in the operation of mining is a rewarding investment as it shows the profitable and unprofitable products.

keywords: activity-based costing, mining, mine operation.

1. Introduction

A common challenge in mining is the realistic apportionment of actual costs for each product, co-product, and sub-product that are part of the operation product mix. When cost sharing is done improperly, the profitability assessment of each product can be undermined by incorrect information that compromise the strategic decision-making. The introduction of an analysis methodology of indirect costs properly associated with each specific product can have a significant impact on the operation competitiveness.

Arbitrary division of the indirect costs causes distortions, which affect the profitability of each product. As in a new project, where underestimating the costs may cause an unprofitable project's ongoing progress and fail, while overestimation of cost could result not progressing ahead a potentially profitable project (Sayadi *et al*., 2014), the same happens with products in a product mix in a mining operation.

Unprofitable products continue in production, negatively affecting the cash flow. Products that are more profitable are not prioritized, reducing the overall profitability of the mine. With a control of the actual costs of each product, the sales price can be adequate and the most profitable products can be prioritized, positively affecting the company.

The introduction of new management practices, due to mines size, increased automation and the outsourcing of non-core activities, increased the indirect costs and decreased the direct costs (Sartorius and Kamala, 2007; Crowson, 2003). Curry et at. (2014) showed that in a study with 63 mines, the cost related to General and Administration represents up to 42% of the total mine cost. Therefore, the indirect costs are a significant part of the amount to be arbitrarily divided between the products.

The Activity-Based Costing (ABC) Approach is a cost and management tool for decision-making on product mix. The direct and indirect costs (such as administrative, warehouses, sales, maintenance …) can be mapped to identify the relationship between activities and products. The appropriate apportionment of costs and the product mix, thus obtaining the actual profitability of each. The steps to implementing ABC described by Chartered Institute of Management Accountants (2008) are reviewed and applied to the mining industry.

In order to overcome observed bottlenecks in the cost apportionment in product mix in the mining area, this paper emphasis on the introduction of a methodology to deal with the problem.

2. Materials and methods

There is no best cost-benefit analysis, but as Lind (2001) identified, the Activity-Based Costing (ABC) approach is more appropriate to obtaining operating costs in a South African coal mine than the traditional costing techniques.

ABC is a cost accounting methodology, aimed at allocating costs properly. ABC uses cost drivers to appoint the costs to activities and basis of a cause and effect relationship with the products (Kostakis *et al.*, 2008).

According to Chartered Institute of Management Accountants (2008), there are four steps to implementing ABC. Following are these steps applied to the mining industry.

1. Determine activities

The mining needs to make an analysis of all operating processes that consist of one or more activities required to generate the product mix.

2. Select resource costs to activities

Determine why the cost occurred by tracing costs to cost objects. Costs are categorized in three:

i. Direct costs are traceable directly to one product. The blast and drilling cost that it takes to generate a product in one mine front are an example of it.

ii. Indirect costs are not traceable to an individual product. They are used to generate more than one product, but not all of them. Truck and shovel maintenance costs that are used in more than one product are example of this.

iii. General costs are not traceable to any product. Whatever product is produced, these costs remain unchanged. Security costs are an example of this.

The classification above is different from the standard Direct, Indirect and Fixed Costs used in which the items are related to production (Pascoe, 1992), not the specific product.

3. Determine products

Determine products for which an activity segment executes activities and utilizes resources.

4. Appoint activity costs to products

Activity drivers appoint activity costs to products based on the utilization for each activities. The key to accurate cost measurement is the correct distribution of the cost drivers (Ai-hua *et al.*, 2009; Gomes *et al.*, 2015).

Figure 1 shows the cost flow in the case study using the ABC approach.

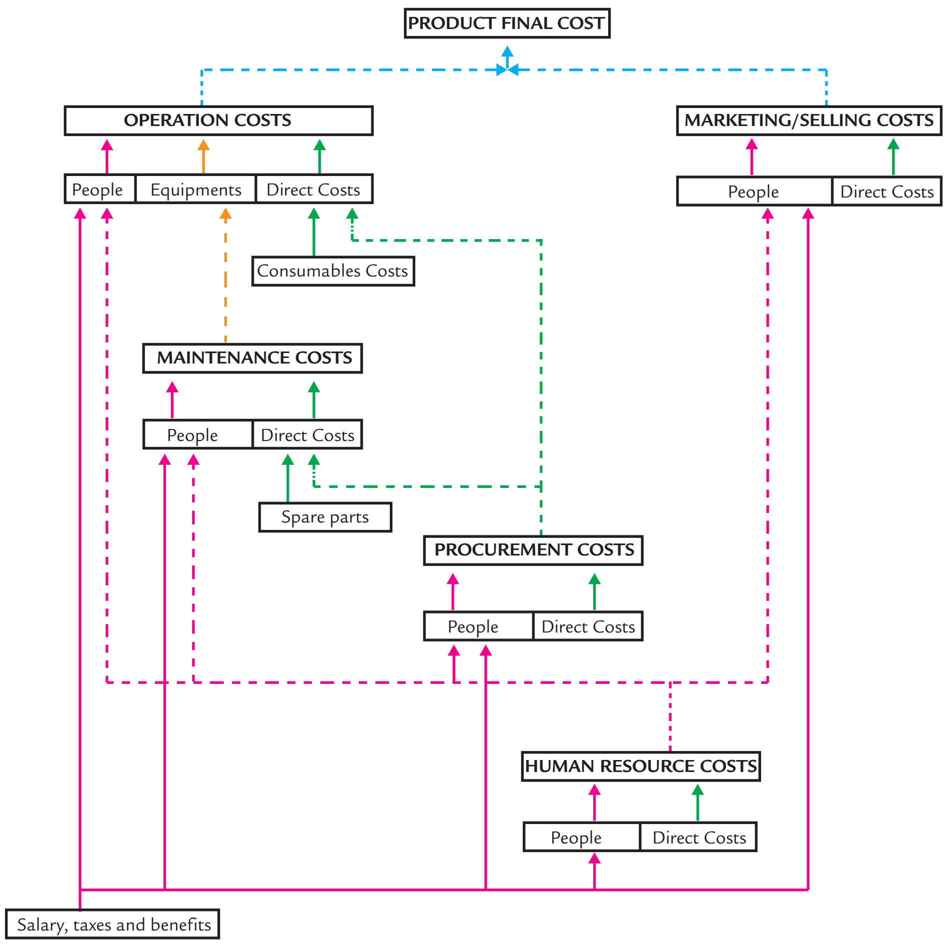

Figure 1
Cost Flow in the case study
using the ABC approach

3. Theory / calculation

3.1 Cost equations

The Total cost of each product has many related activities that generate a lot of cost information to be included in each product. Below is described each step to get the Total cost, considering the Cost Flow described in Figure 1.

- **People**

The cost of the Human Resources (Employees and Direct Costs) is divided equally between the employees of the other areas. Therefore, the cost of an employee (excluding the Human Resources employees) is:

Equation 1
$$C_{peY} = S_{peY} + \frac{C_{HR}}{(N_{pe} - N_{peHR})}$$

Where: C_{peY} = Cost of the employee "Y"; S_{peY} = Salary and charges of the employee "Y"; C_{HR} = Total Cost of Human Resources; N_{pe} = Number of employees in the mine; N_{peHR} = Number of employees in the Human Resources.

- **Direct Cost**

The Direct costs are:

Equation 2
$$C_{dcZ} = DC_Z + C_{pe\,\mathrm{Pr}} \bullet \frac{NO_Z}{NO_{\mathrm{Pr}}}$$

Where: DC_Z = Direct Cost of item "Z"; C_{pePr} = Procurement Cost; NO_Z = Number of orders related to item "Z"; NO_{Pr} = Total Number of orders.

- **Equipment**

The cost of any equipment is:

Equation 3
$$C_{eqK} = C_{MAeqK} + C_{dceqK}$$

Where: C_{MAeqK} = Cost of the maintenance the equipment "K"; C_{dceqK} = Direct cost of equipment "K" (oil, gas, spare parts, ...).

- **Maintenance**

Ali and Reza (2013) showed that maintenance and overhaul represent from 32% to 64% of the total operating cost for a wheel loader equipped with a cable shovel. So, maintenance cost needs to be evaluate with attention.

The cost of equipment maintenance is:

Equation 4
$$C_{MAeqW} = \sum_{i=1}^{n} (C_{peMi} \bullet \%T_{peieqW}) + C_{dcMeqW}$$

Where: C_{peMi} = Cost of the maintenance employee;
$\%T_{peieqW}$ = Percentage of time that maintenance employee "i" works in equipment "W";
C_{dcMeqW} = Direct maintenance cost of equipment "W" (broken parts, ...).

- Marketing

The cost of any marketing/selling is:

Equation 5
$$C_{MarkX} = C_{dMarkX} + \sum_{i=1}^{n} (C_{peMai} \bullet \%T_{peMaiPX})$$

Where: C_{dMArkX} = Direct Cost of Marketing/selling related to product "X"; C_{peMai} = Cost of the Marketing employee "i"; $\%T_{peMaiPX}$ = Percentage of time that marketing/selling employee "i" works related to product "X".

- Total Product Cost

The total cost of the Product "X" is:

Equation 6
$$C_{PX} = \sum_{k=1}^{n_1} (C_{eqk} \bullet \%T_{eqkPX}) + \sum_{y=1}^{n_2} (C_{pey} \bullet \%T_{peyPX}) + \sum_{z=1}^{n_3} (C_{dcz} \bullet \%P_{dczPX}) + C_{MarkX}$$

Where: C_{eqk} = Cost of the equipment "k"; $\%T_{eqkPX}$ = Percentage of time that equipment "k" operating in product "X"

or related to it;
C_{pey} = Cost of the employee "y";
$\%T_{peyPX}$ = Percentage of time that employee "y" works related to product "X";
C_{dcz} = Direct Cost on step "z";
$\%P_{dczPX}$ = Percentage of direct cost "z" related to product "X";
C_{MarkX} = Marketing and Selling costs related to product "X".

$$
\begin{aligned}
C_{PX} = {} & \sum_{k=1}^{n_1}\left(\left(\left(\sum_{i=1}^{n_4}\left(C_{peMi} \bullet \%T_{pekeqk}\right) + \left(DC_{Meqk} + \left(\left(S_{pe\,\mathrm{Pr}} + \frac{C_{HR}}{(N_{pe} - N_{peHR})}\right)\right) \bullet \frac{NO_{Meqk}}{NO_{\mathrm{Pr}}}\right)\right) + C_{dceqk}\right) \bullet \%T_{eqkPX}\right) \\
& + \sum_{y=1}^{n_2}\left(\left(S_{pey} + \frac{C_{HR}}{(N_{pe} - N_{peHR})}\right) \bullet \%T_{peyPX}\right) \\
& + \sum_{z=1}^{n_3}\left(\left(DC_{z} + \left(S_{pe\,\mathrm{Pr}} + \frac{C_{HR}}{(N_{pe} - N_{peHR})}\right) \bullet \frac{NO_{z}}{NO_{\mathrm{Pr}}}\right) \bullet \%P_{dczPX}\right) \\
& + \left(DC_{MarkX} + \left(S_{pe\,\mathrm{Pr}} + \frac{C_{HR}}{(N_{pe} - N_{peHR})}\right) \bullet \frac{NO_{X}}{NO_{\mathrm{Pr}}} + \sum_{i=1}^{n_5}\left(\left(S_{peMarki} + \frac{C_{HR}}{(N_{pe} - N_{peHR})}\right) \bullet \%T_{peMaiPX}\right)\right)
\end{aligned}
$$

Equation 7

3.2 Shared resources

Section 3.1 describes the equation of each cost. The focus of this section is to define the cost drives in shared resources, like equipment and employees.

3.2.1 Equipment

In Figure 2 the equipment from secondary crushers are "working" in just one material, which will become the product. Therefore, this equipment "works" 100% of time in the equivalent product. The difficulty is for the equipment that will produce material for more than one product, like a primary crusher. In this case, the primary crusher operates in batches that produce material for each pile, so the cost drive is the time of production for each pile.

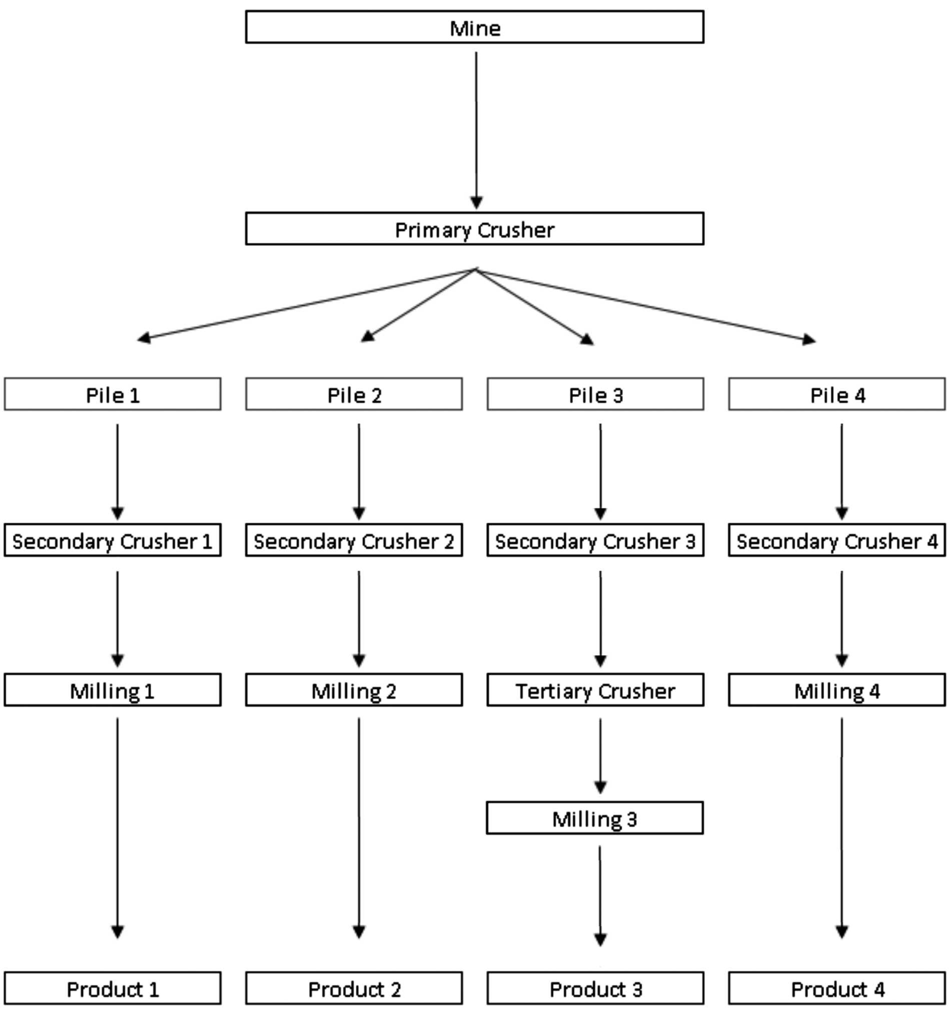

Figure 2
Material Flow – Example 1

In the following figure, there is equipment that produces more than one product and that produces material for other products in continuous operations. The cost drive in this situation is the mass that the equipment operates. Considering the mass of each product "X" as "mpX", Figure 3 shows the mass that enter in each equipment.

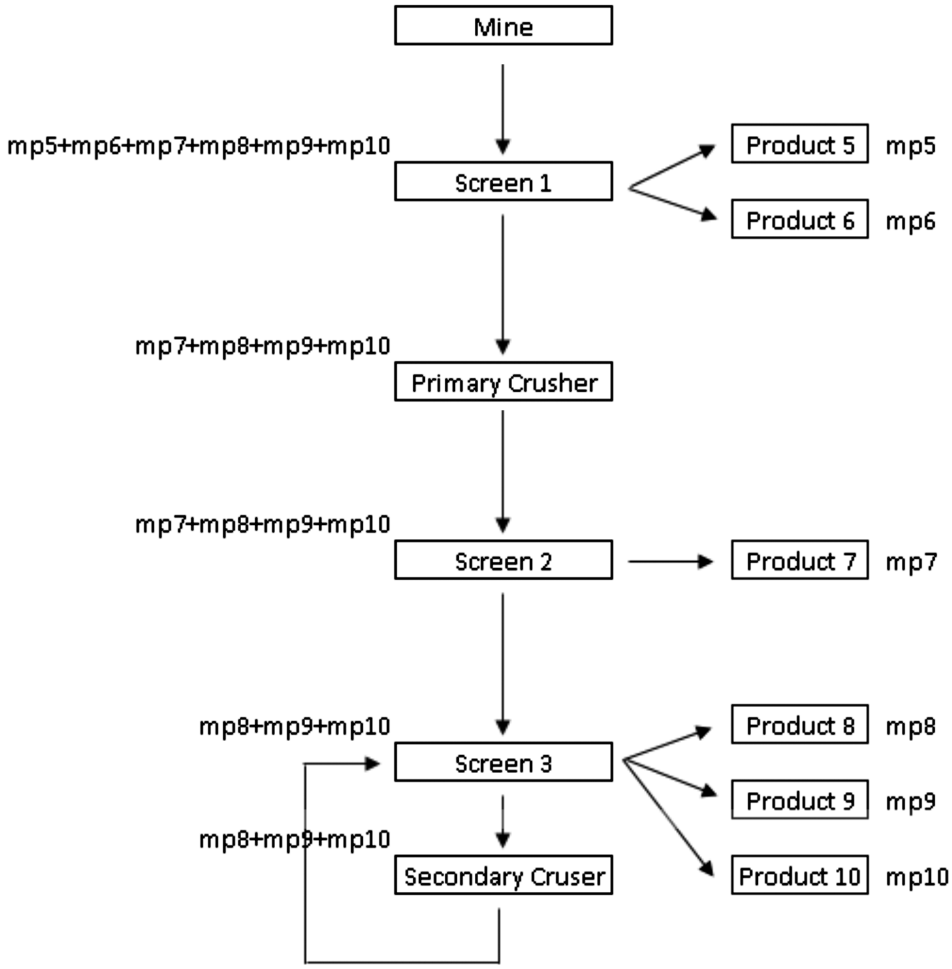

Figure 3
Material Flow with mass – Example 2

Equation 8 shows the equipment cost of product 10.

Equation 8

$$\sum_{i=1}^{5}(C_{pei} \bullet \% T_{peiPX}) =$$

$$C_{pe1} \bullet \% T_{pe1P10} + C_{pe2} \bullet \% T_{pe2P10} + C_{pe3} \bullet \% T_{pe3P10} + C_{pe4} \bullet \% T_{pe4P10} + C_{pe5} \bullet \% T_{pe5P10} =$$

$$mp10 \bullet \left(\frac{C_{pe1}}{mp5 + mp6 + mp7 + mp8 + mp9 + mp10} + \frac{C_{pe2}}{mp7 + mp8 + mp9 + mp10} + \frac{C_{pe3}}{mp7 + mp8 + mp9 + mp10} + \frac{C_{pe4}}{mp8 + mp9 + mp10} + \frac{C_{pe5}}{mp8 + mp9 + mp10}\right)$$

3.2.2 Employees

The operation, marketing/selling and maintenance employees have the time spent at each equipment or product as cost drive. The procurement employees have the number of purchase orders as cost drive. The human resources cost is shared equally by the number of employees.

4. Results and discussion

The Cost Model used the information collected in the period with the equations shown in section 3. The result shown in Figure 4 shows the costs by product and the selling price of each.

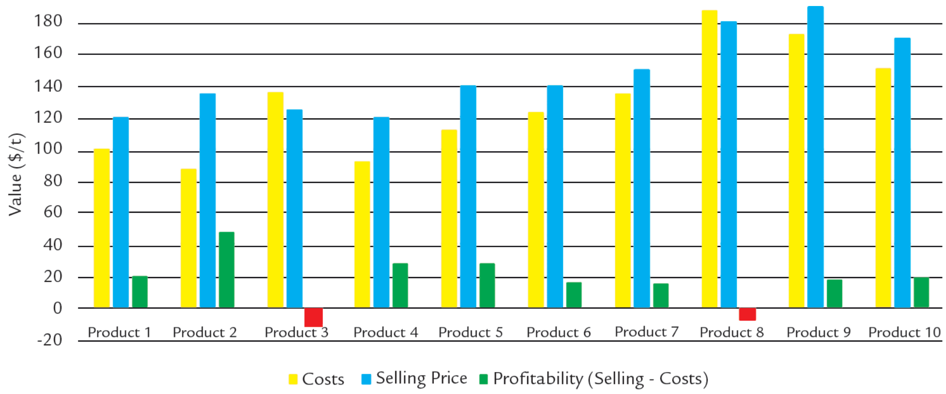

Figure 4
Profitability of each product

The products 3 and 8 have negative profitability and decrease the mining global profitability as shown in Figure 4.

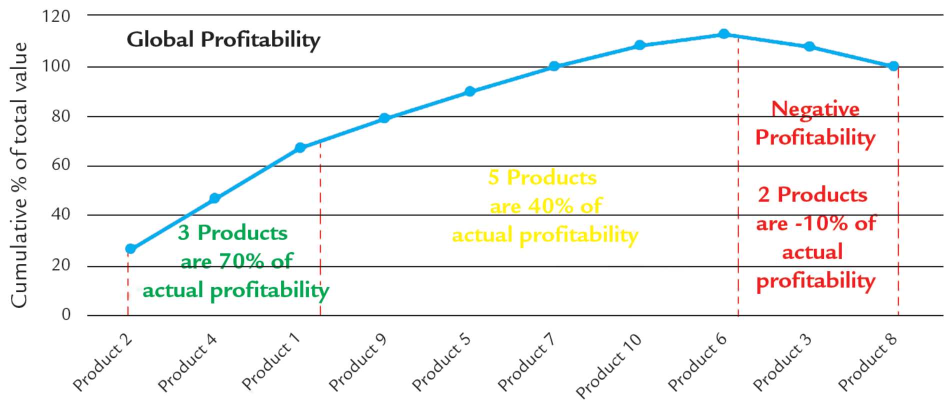

Figure 5
Global Profitability

Considering that the selling price could not be modified and that there is demand for other products, the material that generates product 3 can be changed to product 4, which has positive profitability.

As seen in Figure 3 the product 8 is produced simultaneously with product 9 and 10. The Product 8 decreases a lot the profitability of Products 9 and 10. Considering that the selling price can be changed, the Product 3 and 8 can be reviewed to a higher value.

The most common difficulty was to define the data collection, identification of activities and selection of cost drivers. As shown by Briers and Chua (2001), the changes are cyclical in a company, and the input information needs to be always in reevaluation not to make the product cost evaluation obsolete and then abandoned. Even with the advance of information technology and computer application to the mineral sector (Nader et al., 2012), the innovative approach faces challenges to be used in the mineral area.

5. Conclusion

ABC analysis is more expensive and time-consuming than a traditional cost allocation system, but it can assist in understanding the economic impact of management decisions and in controlling indirect costs.

The appropriate apportionment of cost between the products mix shows the actual profitability of each. This has shown that some product were not profitable and the range of alternatives that can be followed, such as increasing the selling price, decreasing the costs or no longer produce the product.

This study clearly indicates that an ABC approach is efficient for analyzing mining costs with product mix.

Activity Based Costing has far wider applications than the aspect described here. One of these applications is as a management-reporting tool that is covered in other sources.

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