Double Peak and Makomo Resources Practical Training

MAKOMO

Xandro da Silva

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15006931

Department of Chemical Engineering
University of Pretoria

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Contents

Nomenclature

CC	Coking coal	
DMS	Dense Media Separation	
DP	Double Peak	
HHV	Higher heating value	$MJ\,kg^{-1}$
HPS	Hwange Power station	
LA	Low ash coal	
NP	Nuts/peas (blend)	mm
NPD	Nuts/peas/duff (blend)	mm
ROM	Run off mine	
USD	United States Dollar	$
Wduff	Wet duff	mm
Wfines	Wet fines	mm
Wnuts	Wet nuts	mm
Wpeas	Wet peas	mm

1 Introduction

1.1 Background

As required by the Department of Chemical Engineering from the University of Pretoria, all undergraduate students must complete a minimum of six weeks practical training. This training forms a compulsory and integral part of the learning for the student's education. It is essential for the student to gain working experience and knowledge outside of a university setting, ideally in a chemical plant. Allocation of a problem (from the employer) should test the ingenuity of the student.

Makomo Resources is the largest privately owned coal mine in Zimbabwe. Located in the coal mining town of Hwange in northwestern Zimbabwe. Makomo strives to provide quality coal products to Zimbabwe's power stations as well as its industrial and agricultural sectors. The mine is composed of open cast pits where coal is extracted and processed into specific products. The processing plants are sub-divided into a dry plant sector and a wet plant sector, or as it is known as the DMS plant. Once the coal products are processed, they are delivered to the requested costumers via truck or rail transport.

Double Peak is a company based in Johannesburg that has stakes in a number different business ventures, one of which is Makomo Resources. Double Peak finances the mining operations and owns the process plants. Contractors such as Shangano Crushers are hired to process the coal into specific products. All coal product sales are received to Double Peak.

1.2 Problem Statement and Objectives

The practical training done for this report was dynamic and diverse, a number different problems were presented. The first problem presented by Makomo was to find a scientific way to measure ROM and coal products being loaded into and out of the process plants. This is a major issue for the mine as the production tonnage figures do not correlate with the sales tonnage figures. The second problem was to investigate the performance of the 28 mm wet peas production for 2019. Lastly, come up with a cost model for the DMS plant.

The first objective was to investigate the current measuring standard used on the mine; survey and the bucket factor system. The bucket factor investigation must take into account all the different loader types vehicles and ROM types, later these results will be compared with the Shangno bucket factors. Results from the bucket factor investigation will also be compared with the survey verification investigation.

The second objective was to gather information for the 2019 wet peas production. There afterwards, an analysis will be done and the 28 mm peas will be compared with the 25 and 32 mm peas.

Lastly, an in-depth investigation and understanding will be done on the DMS plant. It was important to do this in order to understand what information must be gathered to build a effective cost-model for the DMS process.

2 Theory

2.1 Mining operations

2.1.1 Open-cast versus underground mining

Makomo mine is an open-pit or open-cast coal mine, whereby blasting and material excavation occurs in block sections. According to AngloAmerican (2020) ,open-cast mining is done when valuable mineral or ore deposits are close to the surface. Underground mining is a process that requires tunnelling into the earth's surface to retrieve ore or mineral deep underground where the rock is usually hard and can support overburden (for tunnelling). In contrast, tunnelling near the surface is not practical since overburden is thin and structurally unstable. One of the biggest benefits of open-cast mining is the low capital and operating costs. The biggest disadvantage is the huge ecological change to the land such as changes to the vegetation, bedrock and groundwater levels.

2.1.2 Geology of coal

Coal is a combustible sedimentary rock that is found in coal seams near the surface of the earth. Amongst other geological indications, coal deposits are usually found below sandstone deposit layers. Makomo categorises coal seams according to its percentage ash content (mass basis). The higher the ash content the lower the HHV of the coal seam and therefore the value of the coal product(higher the HHV, the more valuable the product). Figure 1 illustrates how a typical coal seam deposit looks like:

Shale is a form a coal, however its ash content is too high (greater than 30%). There is no commercial use for shale and it is therefore used for land refill and rehabilitation process

Figure 1: Typical cross-section of a coal seam deposit (NOTE: seam layers are exaggerated for better clarity)

after mining operations have been completed. All PC (Power coal) mined and produced is sold to HPS for power generation. Low ash coal is used for fire-coal based boilers in the agricultural, tobacco, distillation and refinery industries. Coking coal is exclusively sold to the steel manufacturing industry for its high HHV. Table 1 below shows the ash contents of the different types of coal seams:

Table 1: ROM coal types

Type	% Ash content
PC	20-30
PC2 (18%)	15-18
LA	10-15
CC	less 10

2.2 Coal Products

Makomo produces various coal products according to its customers' needs. Products vary in its sizing and coal type (ash contents) and are sold to the Zimbabwean economy and external exports. Table 2 and Table 3 illustrate the different coal product sizing and coal products sold respectively.

Table 2: Makomo coal product sizing

Name	Sizing	Unit
Cobbles	50-80	mm
Nuts	30-50	mm
Peas	10-32	mm
Duff	4-10	mm
Fines	0.5-4	mm

Table 3: Makomo Resources coal product price list

Coal Product	USD per ton
HPS PC	27.50
Wpeas (32mm)	70
Wpeas (25mm)	70
Wnuts	70
Dry peas	60
NPD	58
NP (18%)	50
Cobbles	55
Cobbles (18%)	55
Rounds	55
Rounds (18%)	55
Wduff	27
Wfines	27
CC peas	80
CC nuts	80
CC duff	80
CC fines	80

2.3 Survey

Survey is a technique that is used to measure ROM and coal product stockpiles. It makes use of a mapping software that can approximate the volume of a stockpile. A surveyor, carrying a mapping device, walks all over a stockpile and successfully maps out the stockpile. From there, the information is inputted into the software and the volume of the stockpile is determined. Samples are constantly taken from the stockpile to determined its density. Once the density and the volume are known, the mass of the stockpile can be determined.

3 Bucket Factor and Survey Verification

3.1 Bucket Factor Investigation

The bucket factors of each loader and ROM type was determined and compared with the bucket factors used by Shangano. A detailed procedure of the investigation is stipulated below:

Procedure:

1. An empty truck is weighed on the weigh bridge and the mass is recorded.
2. A specific loader loads one scoop of specific ROM into the empty truck.
3. The truck and ROM are weighed and the mass for one scoop is recorded (determined on the mass difference of the ROM filled truck and empty truck).
4. Steps 2 to 3 are repeated to record the mass of one scoop another two times.
5. The average of the 3 scoops is calculated to have an overall bucket factor.

This procedure was conducted using PC1, PC2, Slurry and LA. The CC seam had not been mined yet. It was assumed that the weigh bridge was calibrated and therefore accurate in the measurement of the actual bucket/scoop weights. There were some challenges faced such as availability of diesel or no electricity to use the weigh bridge that hindered the investigation. As a result, some trials were left incomplete and trials for other loaders were not completed at all. The results of the bucket factor investigation are shown below as Table 4.

Table 4: Results of bucket factor investigation versus Shangano bucket factors

Power coal					
Loader	**Trial 1**	**Trial 2**	**Trial 3**	**Average**	**Shangano**
JBO4	4.4	4.02	4.52	4.31	2
S62	6.26	5.84	-	6.05	4
L25	5.12	5.12	5.1	5.14	4
Power coal (18%)					
Loader	**Trial 1**	**Trial 2**	**Trial 3**	**Average**	**Shangano**
JB04	4.14	3.8	3.9	3.95	2
S62	6.1	5.76	5.06	5.64	4
L25	4.96	4.74	-	4.85	4
Slurry					
Loader	**Trial 1**	**Trial 2**	**Trial 3**	**Average**	**Shangano**
S62	5.31	5	5.32	5.21	-
Low ash					
Loader	**Trial 1**	**Trial 2**	**Trial 3**	**Average**	**Shangano**
S62	4.5	4.28	4.78	4.52	4.8
L25	4.02	4.92	4.56	4.5	3.8

From Table 4 it can be deduced that the biggest variance between the measured bucket factors and that of Shangano were with PC and PC (18%) ranging from a variance of 1 to 2 tons. The reason for this variance can be due to a number of factors:

- Difference in measured densities between Shangano and the investigation.
- Human error was not taken into account such as inconsistent scoop loading or not all the material in the scoop was off-loaded.
- Material clinging onto the bucket as observed with wet slurry.
- Not enough trials were done to decrease the percentage error of the investigation and therefore the accuracy of its results.
- The device used by Shangano to measure the bucket factors and the investigation's (weigh bridge) might of been different.
- It was assumed that the weigh bridge was calibrated, this however was not the case.

3.2 Survey verification

To verify survey using the weighbridge and to test the bucket factors obtained from the previous exercise. The results of the investigation were then recorded in Table 5. Procedure of the invetigation is shown below:

Procedure:

1. Weigh an empty truck using the weigh bridge and record down its mass.
2. Fill the truck with ROM to its capacity.
3. Weigh the filled truck using the weigh bridge and record down the mass. Using the difference between this new mass and the mass of the empty truck. The weight of the ROM is determined.
4. The trucks then dump the ROM on a cleared area where survey measured the contents.
5. Steps 2 to 4 were repeated again using a different.
6. The results were compared with the estimated mass calculated using the DP team's bucket factors.

Table 5: Results of survey verification investigation

Loader	Number of loads	Predicted bucket factor (t)	Survey (t)	Actual Mass (t)
JB04	8	33	25.6	27.2
JB04	7	31	19.1	24.9
Total:		**64**	**44.7**	**52.1**

From Table 5, there is significant variance between both survey and bucket factor mass, against actual mass determined from the weigh bridge. Reasons for this huge variance are similar to the bucket factor investigation such as variance in densities and the weigh bridge not being calibrated. However, what is a big concern is the large variance in the actual mass and the bucket factor tally (from the previous experiment), since both experiments used the same weigh bridge. Even though the weigh bridge was not calibrated, both investigations worked under the same experiment conditions and therefore both should theoretically match, i.e. the uncalibrated bridge.

Based on the results from both investigations, there is no consistency with the variance of survey or bucket factor and it can be concluded that both methods are unreliable. The tallying method using bucket factors has a lot of human errors and errors where loader operators can fill up each bucket with different masses on each load. Also, survey is limited on how accurately the surveyor maps out the stockpile and again this leads to human error. It is therefore highly recommended that automation in the use of weightometers are installed into the process plants for more accurate input and output tonnages. Also, it should be insured that the weightometers and the weigh bridge are constantly calibrated to ensure measurements are in cohesion with one another.

4 Wet Peas Production

Low ash wet peas is a popular coal product sold by Mokomo mine and is the second most valuable product sold, at $70/ton, after coking coal products. Thus, it was important to investigate the production of wet peas for the year of 2019. Wet peas are exclusively produced by the DMS plant, ROM is fed to plant 2 and then into the DMS. Information for 2019 was gathered from numerous sources and compiled into one excel spreadsheet.

Note: production data was only given for the months of January to October, no information was available for the months of November and December.

From the month of May on wards, Makomo executives agreed to produce only 28 *mm* wet peas instead of the 25 and 32 *mm* peas. Reason for this was because of customer demands. Customers found that the 25 *mm* peas burned at the ideal rate when used in their conveyor-fed boilers. It was found that that the 32 *mm* peas took must longer to burn and some were still found burning in the ash stockpiles. However, 32 *mm* peas are produced much quicker and in higher yeilds as compared to the 25 *mm* peas. Therefore as compromise was made with Makomo and its' customers to produce the 28 *mm* peas as this solution benefited both parties.

The first thing that was analysed was to see how wet peas production (actual) compared to production targets for 2019. Figure 2 illustrates the production target and actual in tonnage per month for 2019, also open stock from the previous month is shown.

From Figure 2, it is clear that actual production did not equal or exceed production targets, except for the month of April. There could be a number of factors that cause this such as no diesel availability or no electricity on the mine. However, in-depth investigation for each month to see what caused targets not being meet was not done. Another factor to consider is the unreliability of the bucket factor and survey methods. As concluded in the previous section, there was significant variance between the weigh bridge measurements and the two methods. Wet peas produced is determined from sales sold, by which the product was measured using the weigh bridge.

Next the percentage yields for each product per month was determined for LA inputted into the DMS plant. This was done using Equation 1.

$$\% \text{ Yield} = \frac{\text{Wpeas produced}}{\text{Total LA Input}} \times 100 \tag{1}$$

Figure 3 illustrates the 2019 percentage yields for wet peas. It is observed that 25 *mm* peas have lower percentage yields than the 32 *mm*. This makes sense because the 25 *mm* peas take longer to go through the DMS screens as compared to the 32 *mm* peas. The 28 *mm* peas have the highest yields out of all of the three pea sizes, which makes sense since all the LA ROM inputted into the DMS is for the 28 *mm* peas and has to go through one screen sizing (instead of multiple screens for the 25 and 32 *mm* peas production).

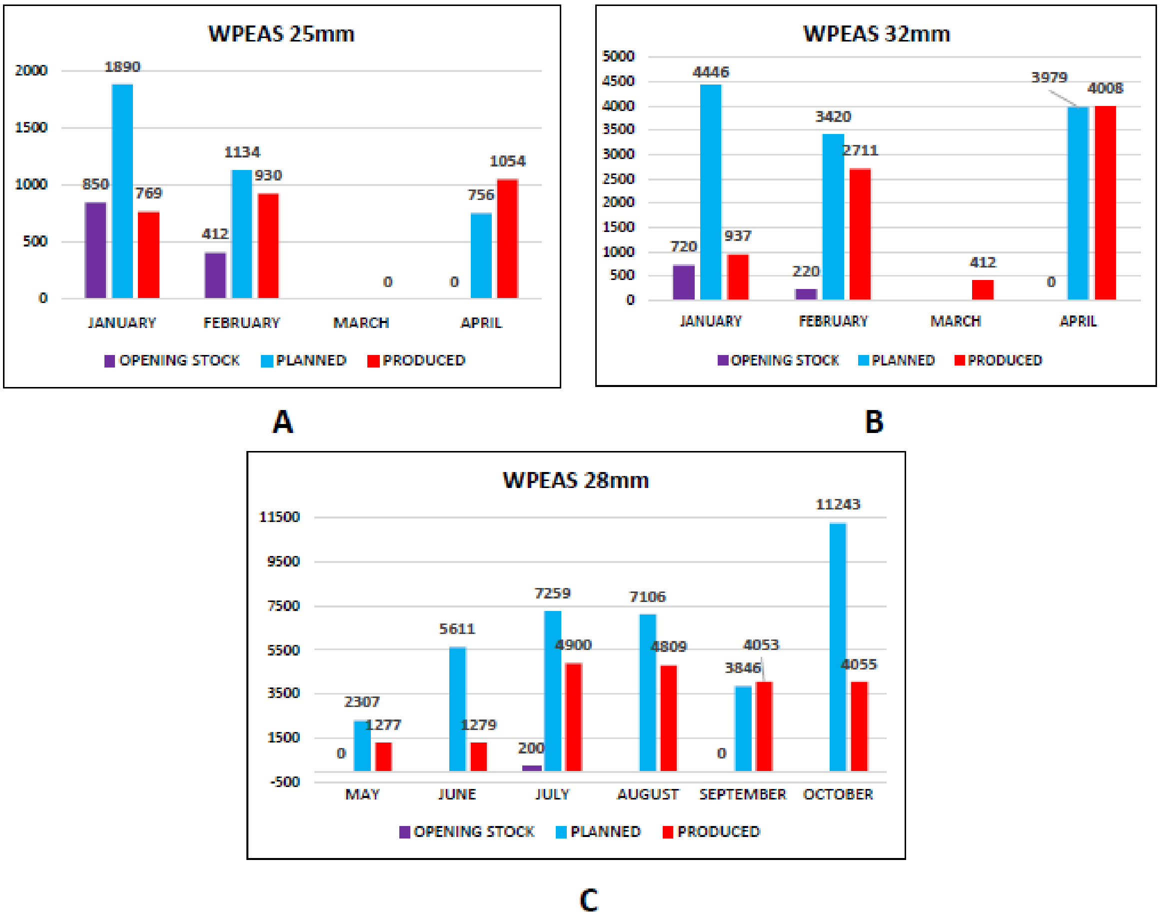

Figure 2: Wet peas: production targets vs. actual for 2019

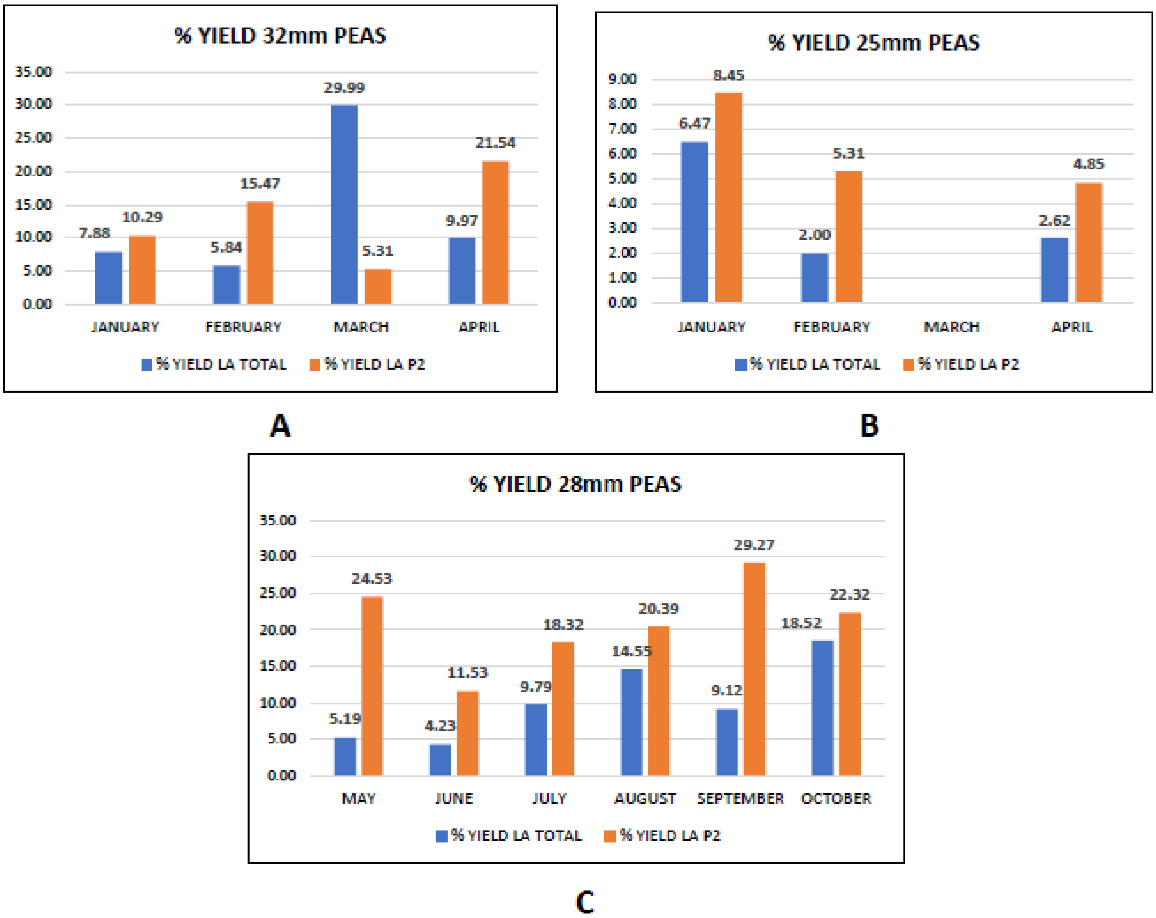

Figure 3: 2019 wet peas percentage yields

The percentage yields are shown in Table 6 and Table 7. Both the 25 and 32 *mm* peas were added together for the total wet peas produced using Equation 1. The reason for this was to see how the overall production of both peas products compared with the total production of the 28 *mm* peas. On initial intuition, the 28 *mm* peas should have a higher yield than the two peas combination based on knowledge that the 25 *mm* peas take longer to be produced and have the lowest yields.

Table 6: percentage yield for the combination of the 25 and 32*mm* wet peas.

Month	Total LA % yield	Total Plant 2 (DMS) % yield
January	14.35	18.74
February	7.85	20.78
March	29.99	21.54
April	12.60	23.28
Average:	**17.39**	**20.35**

Table 7: percentage yield for the 28*mm* wet peas.

Month	Total LA % yield	Total Plant 2 (DMS) % yield
May	5.19	24.53
June	4.23	11.53
July	9.79	18.32
August	14.55	20.39
September	9.12	29.27
October	18.52	22.32
Average:	**10.23**	**21.06**

The results from Tables 6 and 7 indicates that the 28 *mm* peas did have a slighter higher average percentage yield for plant 2, at 21.06%, as initially hypothesised. This is a positive sign that proves that the switch to the 28*mm* peas was the correct decision to satisfy both Makomo's customer needs and still maintain high percentage yields.

5 Estimation of DMS Costing

In the interest not to disclose DP and Makomo's financial statements, this report will not discuss in detail the DMS cost model that was developed. However; aspects such as theory and the assumptions that were made to construct the model will be discussed below.

5.1 Estimation of Manufacturing Cost

According to Turtan *et al* (2018: 236-238), there are three categories that affect the cost of manufacturing (COM): direct costs (DC), fixed costs (FC) and general expenses (GE). Direct costs are operational costs that are directly dependent with the rate of production such as raw materials, water treatment, operating labour, etc. Fixed costs are costs that do not vary with the rate of production, examples of this cost are depreciation of the process plant,insurance and local taxes. General expenses are costs that are not directly related to the manufacturing process. The total COM can be obtained by adding all three categories together as shown in Equation 2:

$$\mathrm{COM} = \mathrm{DC} + \mathrm{FC} + \mathrm{GE} \tag{2}$$

5.2 Assumptions used in cost model for the DMS

- Down payment value was excluded.
- Lasher's wages per hour information was acquired from the 2017 budget.
- Electricians, welders and fitter's wages were averaged from the 2017 budget.
- Maintenance part's values are from the 2019 monthly "purchase report".
- Fluculant amount and price used was obtained from the mine, 120.33 RTGS/kg.
- The value of magnetite used per day was obtained from the mine.
- The cost of magnetite is from the 2017 budget.
- Water usage and price was obtained from the mine at 20 000 litres per day at 7 RTGS/kg.
- Lime usage was obtained from the mine and is priced at 6.41 RTGS/kg.
- The electricity usage and value is from the 2017 Budget.
- Operator wages were acquired from the 2017 Budget.
- The loaders' diesel used at the DMS was estimated.
- Working hours per day was estimated at 10 hours per worker.
- Monthly tonnage processed and running hours at the DMS were acquired from Shangano's monthly report.

5.3 Challenges and DMS costing

The biggest challenge that was encountered when developing this cost model was acquiring information. Often things had to be assumed and older prices had to be used in order to estimate the COM for the DMS plant. This made the model inaccurate and it should not be used as the definitive costing for the DMS process. However, an average cost per ton was obtained at $6.39/ton.

6 Conclusions and Recommendations

The main conclusion for the bucket factor and survey investigation is the unreliability of the two methods. Both are heavily susceptible to human error and there is no consistency with there results. It is highly recommended that weightometers are installed into the plants for more accurate input and output tonnages. It is also advised to constantly calibrate both the weightometers and the weigh bridge to ensure that both are in cohesion with one another. This in turn will see better clarity with products produced from the plants and tons sold to customers using the weigh bridge.

From the wet peas investigation it was found that throughout the year of 2019, actual production was not meeting production targets. However, it was found that the switch in production to the 28 mm peas did have a higher percentage yield compared to the combination of the 25 and 32 mm peas. It is recommended that further investigation should be done for all other products sold to see if they are meeting production targets. Also in-depth analysis should be done for each month in the 2019 wet peas production to find a cause why targets are not being met.

Finally, cost of manufacturing for the DMS plant was found to be $6.39/ton. However, this result is not accurate as a lot of assumptions were made and old information was used. It is recommended that better capturing of information and prices for the DMS process be done to ensure better cost models can be done.

References

AngloAmerican (2020) *Open-Pit Mining Definition* URL: https://www.angloamerican.com/futuresmart/our-industry/mining-explained/mining-terms-explained-a-to-z/open-pit-mining-definition (visited on 01/29/2020).

Turtan, R, Shaeiwitz, JA, Bhattacharya, D and Whiting, WB (2018) *Analysis, Synthesis and Design of Chemical Processes*, 5th ed. Prentice Hall.