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PREDICTION MODEL FOR QUANTITY OF MECHANDIZED LONGWALLS IN HA LAM COAL JOIN STOCK COMPANY - VINACOMIN

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Abstract: *Vinacomin is among firms applying successfully merchandise to coal mining. However, the company's output depends on many factors such as height mirror stage, Length oven mechanization longwall, recovery height, length extraction column (oven longwalls), labor organization and specific geological conditions. Therefore, it has caused difficulties for the company in the implementing of production plan. The authors conducted the survey, and collected data from 2017-2019 as a basis for building a prediction model for quantity. Research results help the company to proactively plan, thereby to overall improve productivity and profits and to decrease general manufacturing costs for company.*

Keywords: *merchandise; production plans; prediction model for quantity; mining technology motorization synchronized*

1. OVERVIEW

Ha Lam Coal JSC., - an underground coal mining company in Vietnam Coal - Mineral Group (Vinacomin) is a pioneer of merchanization application in… The company has accompished positive quantity results of… However, the company still has some difficulties and struggles in mining process in CGH: Production organizing charts of mines are consecutively destroyed by changes of mining conditions, concurring incidences affecting significantly planned quantity and proactive deduction of planning of the company.

In order to enhane and optimize technological data that helps the company completes production organizing charts, assign employees and plan proactively mining quantity, the research group has surveyed and collected real data in…. of the company from 03/2015 to 03/2020

Based on collected data, the authors establish a model to forecast mining quantity scale of the company to reduce time, labor for establishing and launching company plans.

2. METHODOLOGY

Multi-variables linear method: The authors use multi-variables linear method to predict quantitative norm with independent variables. After establishing model, the group assess models based on standard criteria to choose the best one for prediction.

Criteria of model selection in research: To choose the optimal model, the research is based on the following criteria

- R2: The model with the same variables, whichever higher R2.
- RMS: The model with the mean square of the lowest residual is selected.
- AIC: The model with the lowest AIC is selected.

3. DATA

The company has 2 CGH lines with a capacity of 600,000 tons / year (CGH1) and 1.200.000 tons / year (CGH2).

* Market furnace with a capacity of 600.000 tons/year: 3 shifts in one day and night deploy 03 flow, equal to 3 cycles. A mining unit includes the following works: mining,

supporting, lowering the ceiling to withdrawn coal on the roof of the market furnace with the progress of 0.6 m/flow, withdrawning for supporting in the transport furnace, the ventilation furnace. The total number of employees as assigned in 1 day and night is 72 employees, with 24 employees per shift.

* Chain-line market furnace with a capacity of 1.200.000 tons/year: 3 shifts in one day and night deploy 02 mining flow, equal to 1 cycle. A mining stage includes the following works: mining, supporting, lowering the ceiling to withdrawn coal on the roof of the market furnace with the progress of 0.6 m/flow, withdawning for supporting in the transport furnace, the ventilation furnace. The inspection and maintenance of market furnace equipment are performed at the beginning of each shift. The total number of employees as assigned in 1 day and night is 90 employees, 30 employees per shift.

Table 1. Parameters of 2 CGH market furnaces

No.	Indicator	Unit	600,000 tons/year	1,200,000 tons/year
1	Seam thickness average	m	14	23.3
2	Seam angle average	degree	5-:- 12	0 -:- 15
3	Length in the direction of the area to the size limit	m	548	325
4	Excavation heigh	m	2.6	3
5	The thickness of the coal layer of lower the ceiling	m	11.4	20.3
6	Length of the market oven	m	118.5	154
7	Exploitation coefficient	-	0.95	0.95
8	Coal recovery coefficient	-	0.75	0.85
9	Number of flow exploited per cycle	shift	1	2
10	Coal mining quantity per flow	T	1284	2372
11	Coal mining quantity per cycle	T	2.182	2.135
12	Mining cycle time	shift	2	3
13	The number of cycle in 1 day and night	cycle	1.5	3
14	Cycle completion factor	-	0.85	0.9
15	Coal exploitation quantity in 1 day and night	T	3273	4270
16	Transition time	day	45	60
17	Coal exploitation quantity in 1 month	T	8.,098	106.745
18	Mining capacity (rounding)	T/year	800.000	1 280 000
19	The number of employees in 1 day and night	Person	72	90
20	Direct labor productivity	T/labor unit	45.5	47.4

The authors surveyed and collected data from March 2015 to March 2020 that are gathered in Table 2 in the order of the months.

Table 2. Summary of database collected about market furnaces

THA	PXU	SLD	SCO	TSL	TKG	TTH	CDV	CCK	CTH	DLC	DCK
03/2015	CGH1	91	25	1.927	1.927		12.6	2.6	10.0	108	
04/2015	CGH1	103	23	18.934	3.912	15.022	13.7	2.6	11.1	108	8.2
05/2015	CGH1	104	25	36.000	7.095	28.905	14.4	2.6	11.8	108	11.0
…											
01/2016	CGH1	126	22	47.794	14.154	33.640	9.1	2.6	6.5	108	31.4
…											
01/2017	CGH1	90	20	65.491	13.597	51.894	13.8	2.6	11.2	121	21.3
01/2017	CGH2	104	20	53.452	7.370	46.082	21.83	3	18.83	155.7	9.8
02/2017	CGH1	88	23	83.946	15.211	68.735	14.4	2.6	11.8	122	31.4
…											
01/2018	CGH1	90	23	36.875	1.788	35.087	5.51	2.6	2.9	118.5	37.4
01/2018	CGH2	106	23	63.610	8.990	54.620	23.75	3	20.75	158.4	11.75
02/2018	CGH1	86	16	41.612	11.973	29.639	9.39	2.6	6.8	118.5	25
…											
01/2019	CGH1	97		78.144			16.4	2.6	13.8	118.5	
01/2019	CGH2	125		75.710			24.6	3	21.6	155.5	
02/2019	CGH1	73		52.590			16.4	2.6	13.8	118,5	
…											
01/2020	CGH1	87		55.315			14.7	2.6	12.1	106	
01/2020	CGH2	90		52.090			24.15	3	21.15	155.5	
03/2020	CGH1	114		83.061			14.7	2.6	12.1	106	
03/2020	CGH2	135		107.621			24.15	3	21.15	155.5	

The collected and described data are according to the results in Table 3. Specifically, the main parameters of the two market ovens as follows:

- In terms of total quantity: CGH1 market furnace has an average monthly quantity of 53.800 tons/month, and CGH2 market furnace's an average monthly quantity is 74.800 tons/month. Combining with Fig 1 to assess the data distribution, it is found that the quantity norm of the CGH2 furnace almost obeys the standard distribution rule, with a distinct bell shape. In contrast, the quantity norm of the CGH1 furnace during this period has large fluctuations and uneven distribution. This is aligned with the reality, because during this time, the CGH1 furnace has changed to a new exploitation site, with different parameters from the original design time.

- In the term of the seam thickness: The average thickness of the coal seam of CGH1 market furnace is 13.3 meters (min 5.00, max 18.7), while that for CGH2 market furnace is 22.9 (min 12.3, max 27.6).

- In terms of mining coal and recovered coal: Most of the mining quantity of the market furnace comes from the recovered coal, because with a very large seam thickness, the company has applied technology to recover coal after mining, contributing to reduce product price.

Table 3. Describe data of 2 market furnaces CGH1 and CGH2

	CGH1 (N=61)	**CGH2 (N=42)**	**Overall (N=103)**
SLD			
Mean (SD)	105 (24.9)	115 (18.8)	109 (23.1)
Median [Min, Max]	101 [9.93, 165]	118 [71.0, 159]	105 [9.93, 165]
Missing	2 (3.3%)	2 (4.8%)	4 (3.9%)
TSL			
Mean (SD)	53800 (29600)	74800 (28300)	62200 (30800)
Median [Min, Max]	58200 [1210, 103000]	74200 [7000, 129000]	65200 [1210, 129000]
Missing	2 (3.3%)	3 (7.1%)	5 (4.9%)
TKG		,	
Mean (SD)	11300 (5860)	12000 (5470)	11500 (5710)
Median [Min, Max]	12000 [1080, 22700]	9750 [1630, 22000]	10300 [1080, 22700]
Missing	18 (29.5%)	22 (52.4%)	40 (38.8%)
TTH			
Mean (SD)	40300 (25900)	66100 (28200)	49200 (29200)
Median [Min, Max]	34700 [0, 86500]	67000 [5370, 108000]	48500 [0, 108000]
Missing	19 (31.1%)	20 (47.6%)	39 (37.9%)
CDV			
Mean (SD)	13.3 (3.18)	22.9 (2.75)	17.0 (5.58)
Median [Min, Max]	14.3 [5.00, 18.7]	24.0 [12.3, 27.6]	16.0 [5.00, 27.6]
Missing	4 (6.6%)	6 (14.3%)	10 (9.7%)
CCK			
Mean (SD)	2.60 (0)	2.98 (0.0905)	2.75 (0.194)
Median [Min, Max]	2.60 [2.60, 2.60]	3.00 [2.60, 3.00]	2.60 [2.60, 3.00]
Missing	2 (3.3%)	4 (9.5%)	6 (5.8%)
DLC			
Mean (SD)	114 (6.29)	155 (6.24)	130 (20.8)
Median [Min, Max]	119 [106, 124]	156 [119, 158]	119 [106, 158]

	CGH1 (N=61)	CGH2 (N=42)	Overall (N=103)
Missing	2 (3.3%)	5 (11.9%)	7 (6.8%)
DCK			
Mean (SD)	23.3 (12.9)	15.9 (7.24)	20.9 (11.8)
Median [Min, Max]	25.2 [0.600, 46.5]	12.9 [2.20, 29.1]	19.4 [0.600, 46.5]
Missing	19 (31.1%)	22 (52.4%)	41 (39.8%)

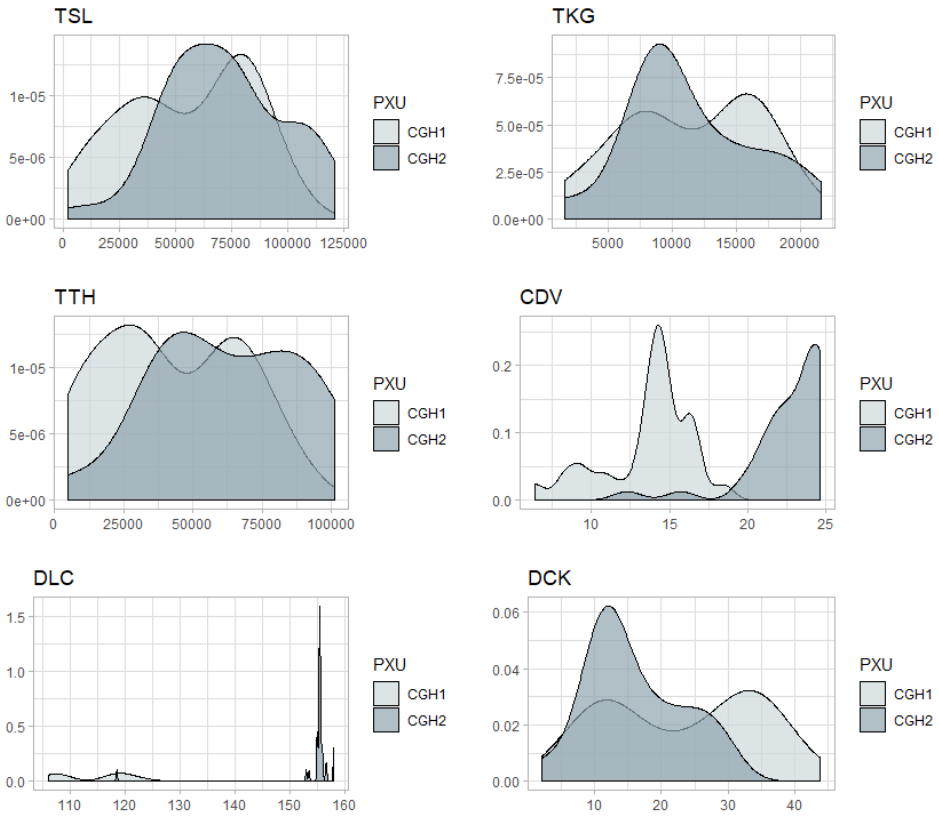

Fig 1. Distribution of data of CGH market furnace parameters

In order to have an overview of the data and correlation level between the furnace parameters, the research team builds the correlation chart in Fig 2.

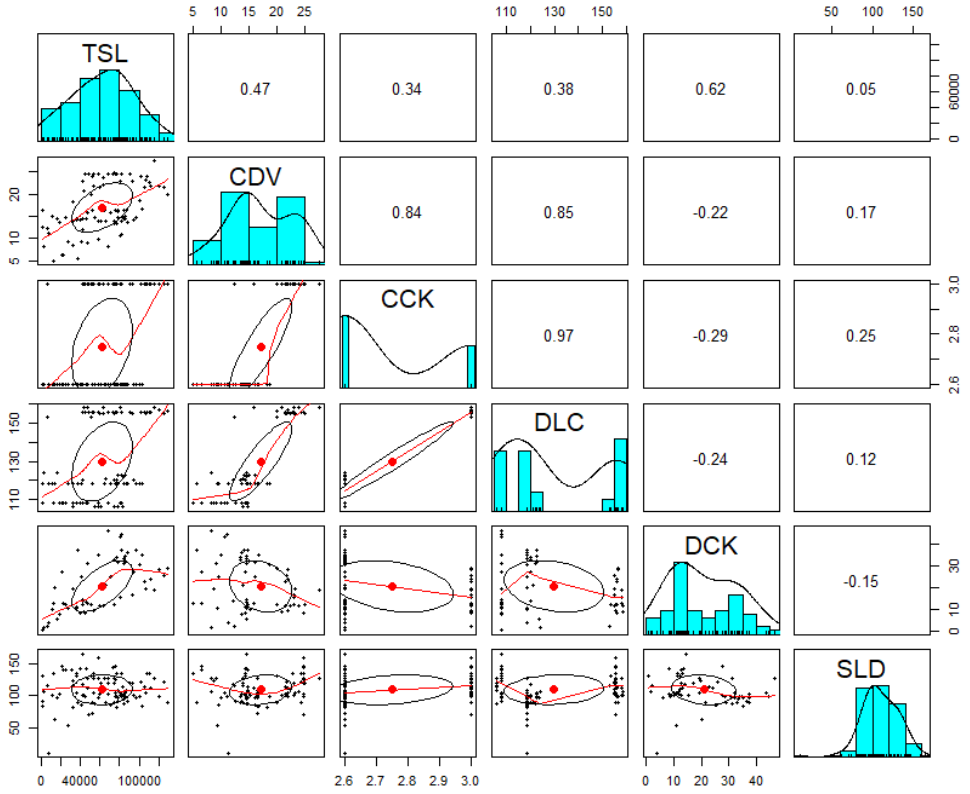

Fig 2. Correlation chart between parameters of the CGH market furnace

Through the chart above, the group found that the quantity norm has the greatest correlation with the length of the stage with a correlation coefficient of 0.62; followed by the seam thickness with a correlation coefficient of 0.47. These can be forecasted as two main factors affecting the company's quantity norm.

4. RESEARCH RESULTS

Run a multivariate regression model between the dependent variable of Total Production (TSL) and the independent variables as seam length (CDV), stage height (CCK), kiln length (DLC), stage length (DCK) and the number of employees (SLD).

Start: AIC=1161.33

TSL ~ CDV + CCK + DLC + DCK + SLD

	Df	Sum of Sq	RSS	AIC
- SLD	1	5.0481e+07	9.6627e+09	1157.0
- CCK	1	1.1993e+08	9.7322e+09	1157.4
- DLC	1	1.9243e+08	9.8047e+09	1157.9
<none>			9.6123e+09	1161.3
- CDV	1	8.4671e+09	1.8079e+10	1194.6
- DCK	1	3.3304e+10	4.2917e+10	1246.5

Step: AIC=1157.01

TSL ~ CDV + CCK + DLC + DCK

	Df	Sum of Sq	RSS	AIC
- CCK	1	7.0571e+07	9.7333e+09	1152.8

- DLC 1 1.4347e+08 9.8062e+09 1153.3

<none> 9.6627e+09 1157.0

- CDV 1 8.7358e+09 1.8399e+10 1191.0

- DCK 1 3.3258e+10 4.2921e+10 1241.8

Step: AIC=1152.81

TSL ~ CDV + DLC + DCK

Df Sum of Sq RSS AIC

- DLC 1 1.0301e+08 9.8363e+09 1148.8

<none> 9.7333e+09 1152.8

- CDV 1 8.6713e+09 1.8405e+10 1186.4

- DCK 1 3.5607e+10 4.5341e+10 1240.5

Step: AIC=1148.8

TSL ~ CDV + DCK

Df Sum of Sq RSS AIC

<none> 9.8363e+09 1148.8

- CDV 1 3.0342e+10 4.0178e+10 1228.6

- DCK 1 3.6052e+10 4.5888e+10 1236.6

It is showed that the quantity norm (TSL) is significantly influenced by two factors: seam thickness (CDV) and the length of the stage (DCK).

Residuals:

Min 1Q Median 3Q Max

-31602 -8626 460 7722 32201

Coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) -50209.1 6692.3 -7.503 4.62e-10 ***

CDV 4245.6 320.2 13.260 < 2e-16 ***

DCK 2165.6 149.8 14.454 < 2e-16 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 13140 on 57 degrees of freedom

(43 observations deleted due to missingness)

Multiple R-squared: 0.8467, Adjusted R-squared: 0.8413

F-statistic: 157.4 on 2 and 57 DF, p-value: < 2.2e-16

The model deliver below outcomes:

The quantity norm = = -50.209 + 4245.6 * Seam thickness + 2165.6 * Stage length

The model has the coefficient R2 = 84.67% and the adjusted R2 coefficient is 84.13%. Thus, 2 factors affecting the output level can explain the difference of 84.67% of the quantity norm. The difference is statistically significant.

Considering the model selection criteria for R2, RMS, AIC, the above model is the best model to explain and forecast the quantity norm for mechanized market furnaces at Ha Lam Coal Joint Stock Company - Vinacomin

Evaluation and analysis of the model residue show the appropriateness of the research model.

The authors continue to analyze the relationship between the model parameters.

Fig 4 shows that with the higher seam thickness, the yield will increase, but with CGH2, the seam thickness of 25 meters is the best, if seams is thicker, the yield tend to decrease. This can be explained that it take more time to withdrawn too thick seams, and the auxiliary work and safety work will be affected, so the quantity may not be reached as expected.

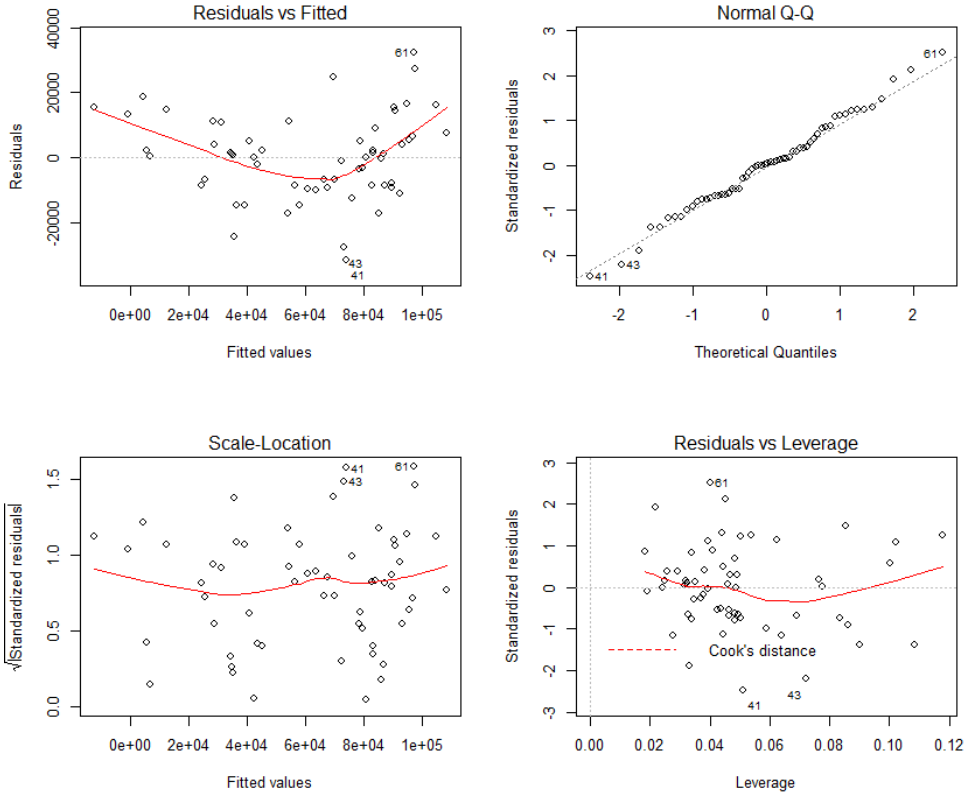

Fig 3. Analysis of the model residue

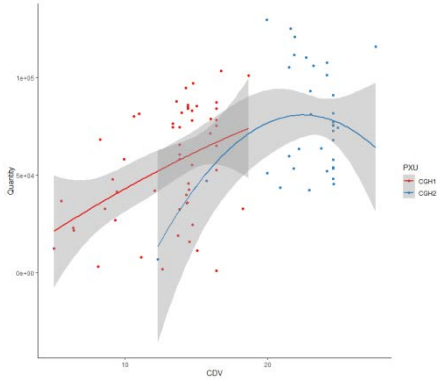

Fig 4. The relationship between the the seam thickness (CDV) and the quantity norm (TSL)

Fig 5 also gives a similar result, the more the length of the stage increases, the more the quantity increases. However, the market oven CGH2 should also remain at 35-40 meters for the best quantity.

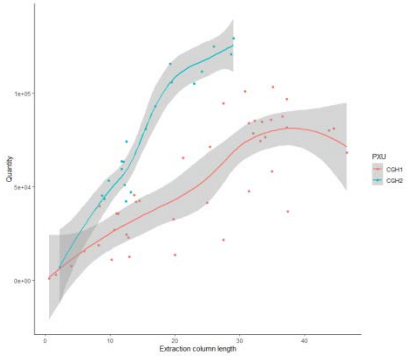

Fig 5. The relationship between the Length of the Stage (DCK) and the quantity norm (TSL)

5. DISCUSSION OF RESEARCH RESULTS

The research has built a model to forecast the quantity norm based on only 2 factors: seam thickness and the length of the stage. The model helps to explain the difference in the yield level of the months with the coefficient R2 = 84.67%.

- The relationship between the parameters of the market furnace helps the company choose the optimal parameters to achieve the expected quantity norm.

- The research still has the following limitations:

+ There are quite a few missing data that makes the model not good.

+ The general forecast for the 2 furnaces having different technological characteristics and technical parameters is not fully reflected in the research results.

+ The study has not analyzed the effects of specific geological conditions on the company's quantity performance.

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