Relationship between Fuel Cost and Other Cost Components - Bench Drilling Phase of Diamond Wire Sawing Technique of Stone Extraction

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Abstract:

In current times mining companies across the globe have to deal with mine mechanization associated cost increments for the sustainable growth of their projects. It has become necessary to anticipate the operational cost and the relationship and impact of various cost components on each other. Unfortunately, dimension stone mining companies and investors in Pakistan have least knowledge about the costs related to diamond wire sawing technique of stone extraction. There is scarcity of literature on the relationship of different cost components associated with this technique. This paper deals with hypothesis testing to prove the relationship of fuel cost with other cost components such as labour cost, consumables cost and maintenance cost. For this purpose Pearson correlation is chosen as the test statistic. The magnitude of correlation ≥ 0.50 and significance level of $\leq 0.01$are set as standard values to prove the hypothesis. The data was taken from dolerite mine of Indus Mining (Private) Limited. It is observed that fuel cost has a highly significant and very strong correlation with labour cost, maintenance cost and consumables cost.

Keywords:

Bench drilling, fuel cost, Pearson correlation, hypothesis testing, diamond wire sawing, dimension stone mining,

I. INTRODUCTION

Mechanization in Dimension stone mining has brought uplift in mining sector across the globe. Modern technologies have caused huge increase in production and more utilization of the valuable mineral deposits. Diamond wire sawing technique is one of the modern mechanized techniques of dimension stone mining. In Pakistan, the introduction of this technique has improved the product value and international acceptability. As compared to blind or semi-blind boulders produced by wedge and feathers technique or drill and blast technique, diamond wire sawing yields squared cut blocks of known features and cut boulders of irregular shape. Production cycle of this technique consists of five phases i.e. bench drilling, bench cutting, bench dropping, block squaring and product loading. Sometimes bench drilling phase is an auxiliary phase can be skipped.

Although diamond wire sawing technique has improved the production and productivity, still investors are unfamiliar about the financial aspects of this technique. Mine planners and technical staff have insufficient data to perform cost-benefit analyses of this technique. There is a misperception that this technique is not cost effective because of high capital cost of machinery and accessories. They have limited fiscal data about this technique to anticipate the improved financial value of the products obtained through diamond wire sawing.

There is a need to assess the financial aspects of this technique and to have a better understanding of the amount and impact of costs incurred during the production cycle of dimension stone mining through diamond wire sawing technique. This paper aims to find relationship between different cost components incurred during bench drilling phase to improve the awareness about financial parameters of diamond wire sawing technique.

A lot of research has been conducted to analyze the operational parameters associated with the diamond wire sawing technique (Mikaiel et al., 2019). Researcher analyzed the impact of diamond wire saw machine performance (e.g. Mikaeil et al., 2018; Jain and Rathore, 2011), and diamond bead wear rate on operational cost incurred in this technique (Careddu and Marras, 2015). Mining companies across the globe have been facing one of the most critical problems associated with high cost trends in their direct mining costs and associated costs (Afum and Temeng, 2014; ICMM, 2012). There is a lack of literature on in-depth description of the financial aspects of each phase of production cycle of diamond wire sawing technique.

II. MATERIALS AND METHOD

The purpose of this paper is to test a relationship between fuel cost and other cost components such as labour cost, consumables cost and maintenance cost, all incurred during bench drilling phase of the production cycle of dimension stone extraction through diamond wire swing technique. The data of incurred costs for the four and a half years was taken from the dolerite (commercial name: black granite) mine of M/s Indus Mining (Private) Limited, one of the prominent dimension stone mining companies of Pakistan. The mine is located in district Mansehra. The company utilized Italian brand DTH drill machine of Marini during the referred time frame. A compatible compressor of Airman Brand (PDS-390S) was used to operate the DTH drill machine.

Bench drilling operations were performed during two shifts of 8 hours each. Fuel cost includes the monthly expenses incurred for fuel consumption and lubricants' consumption. Labour cost is the monthly expenses incurred as salary and other incentives provided to the workers and workers related taxes (recruiter.com, viewed on 1st March 2019) e.g. Employees Old age Benefit Fund and Social Security Fund etc. Consumables cost is the monthly expenses incurred as purchase price DTH bits and other drilling accessories e.g. drill extension rods, pneumatic air pipelines etc. Maintenance cost is one of the major cost component associated with production (Lee and Wang, 1999) and includes the monthly expenses incurred for both reactive and proactive maintenance of the machineries associated with bench drilling.

Hypothesis testing approach is used in this paper. Hypothesis testing is a well-defined procedure which helps in deciding objectively on the basis of available data whether to reject or accept the hypothesis. If r_1 is the correlation between fuel cost and labour cost, r_2 is the correlation between fuel cost and consumables cost, r_3 is the correlation between fuel cost and maintenance cost while the significance level is set at p-value of 0.01 null and alternate hypotheses are stated as follows:

Null Hypothesis (H_0): *There is no significant, strong and positive correlation between fuel cost and other cost components including labour cost, consumables cost and maintenance cost, i.e.* $r_1 < 0.50$; $r_2 < 0.50$; $r_3 < 0.50$ *and p-value > 0.01.*

Alternate Hypothesis (H_1): *There is significant correlation between fuel cost and other cost components including labour cost, consumables cost and maintenance cost, i.e.* $r_1 \geq 0.50$; $r_2 \geq 0.50$; $r_3 \geq 0.50$ *and p-value* ≤ 0.01.

If there is correlation of 0.50 or more and *p*-value (significance level) is less than 0.01, null hypothesis will be rejected. Figure 1 show the parameters selected in this research study to test the strength and significance of relationship between different cost components. In case of results other than that null hypothesis will be accepted thereby leading to the rejection of alternate hypothesis. SPSS [version 17] is used in this research to find the Pearson correlation.

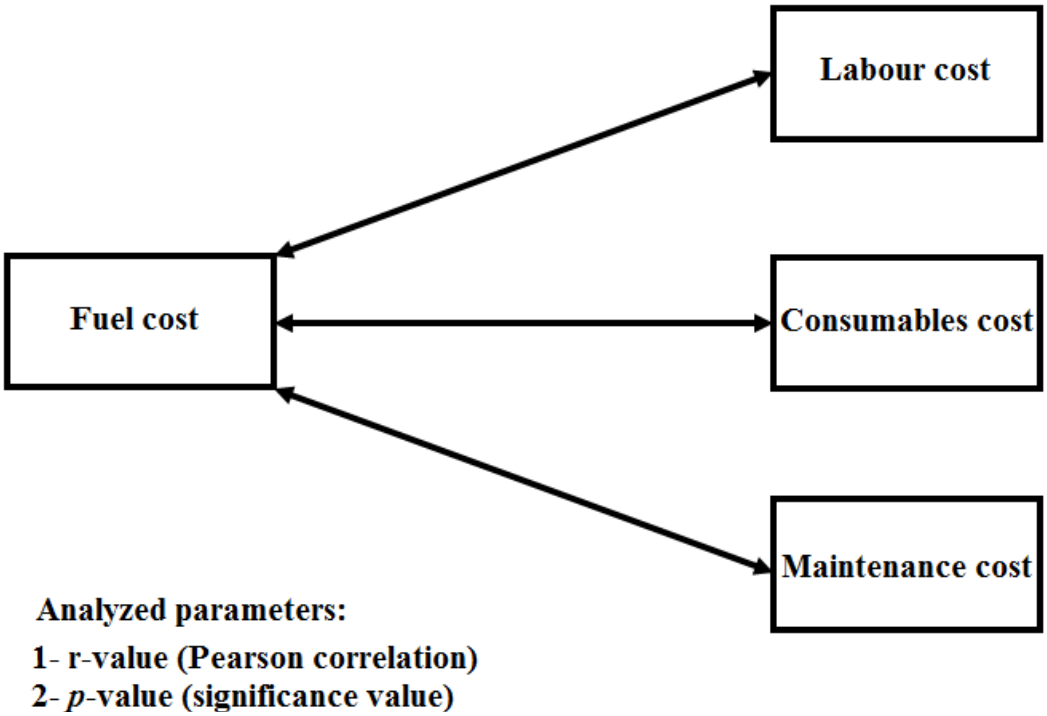

Figure 1: Relationship between different cost components- Analyzed parameters.

III. Analysis and Results

1.1. Correlation:

Table 1 shows the correlation of fuel cost with other variable costs and significance level of each of these correlations. In order to remove any biases from the data, all outlier entries were removed and correlation between different cost components was calculated thereafter.

In table 1, the *p*-value of correlations of fuel components with other cost components is 0.000 in each case which is far below the set significance level of 0.01. This suggests that all the correlation of fuel cost with labour cost, consumables cost and maintenance cost each is highly significant.

Table 1: Correlation of fuel cost with other variable costs (bench drilling phase of diamond wire sawing technique of dimension stone mining (N= 43)

		Fuel Cost (PKR)	Labour Cost (PKR) (r_1)	Consumables Cost (PKR) (r_2)	Maintenance Cost (PKR) (r_3)
Fuel Cost (PKR)	Pearson Correlation	1	0.876**	0.862**	0.874**
	Sig. (2-tailed)		0.000	0.000	0.000
**. Correlation is significant at the 0.01 level (2-tailed).					

Note: All outlier entries removed.

It can also be inferred from table 2 that fuel cost has nearly equal and very strong positive correlation with labour cost (r_1= 0.876) and maintenance cost (r_2= 0.874). Fuel cost has also very strong correlation with consumables cost (r_3= 0.862). The results can be interpreted as an increase in either of the labour cost, consumables cost and maintenance cost also cause an increase in the fuel cost and vice versa.

Figure 2 to 4 graphically represent the correlation of fuel cost with labour cost, consumables cost, and maintenance cost respectively.

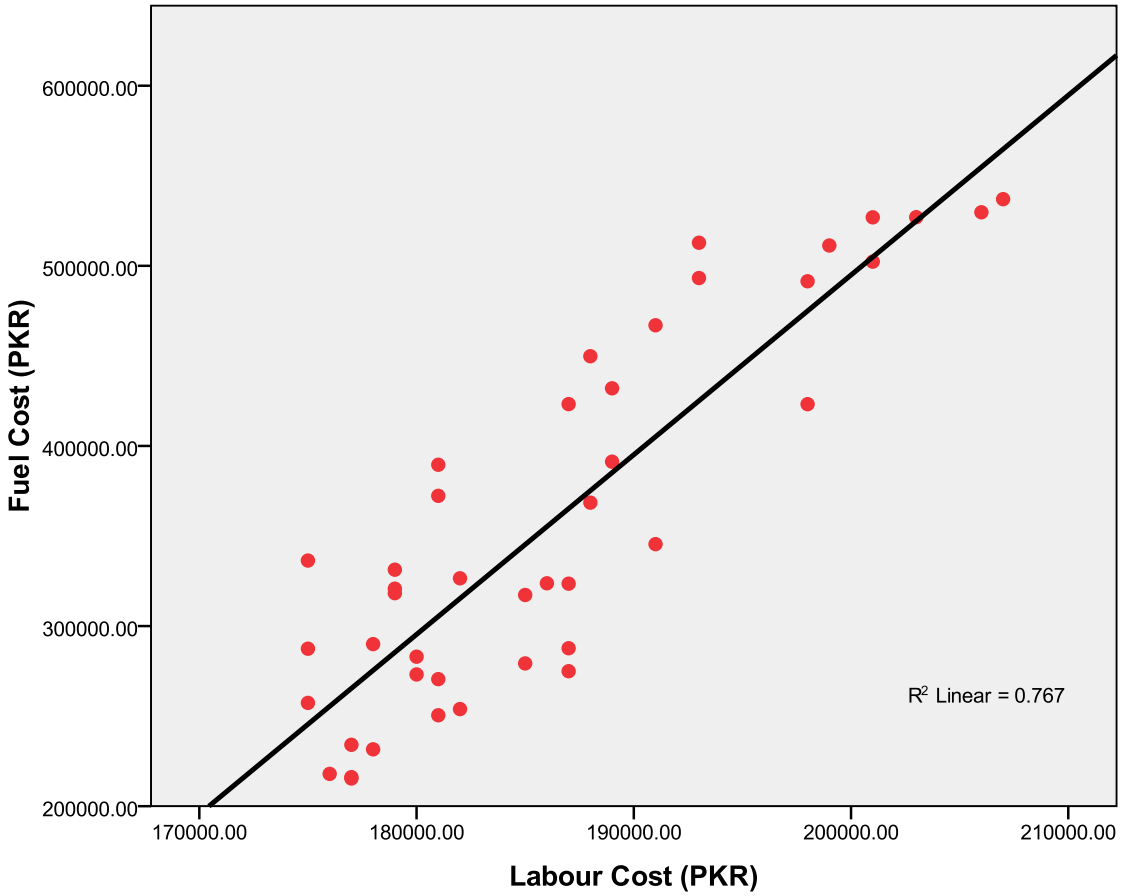

Figure 2: Correlation of fuel cost with labour cost.

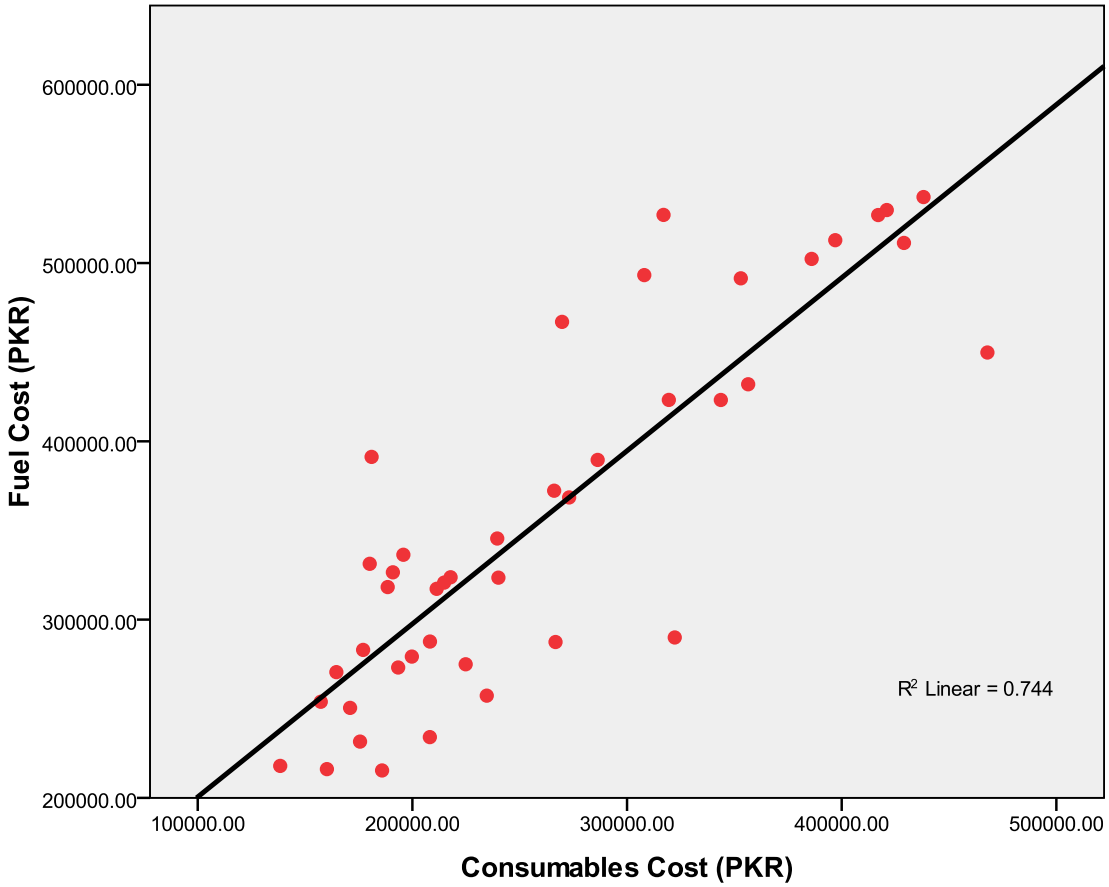

Figure 3: Correlation of fuel cost with consumables cost.

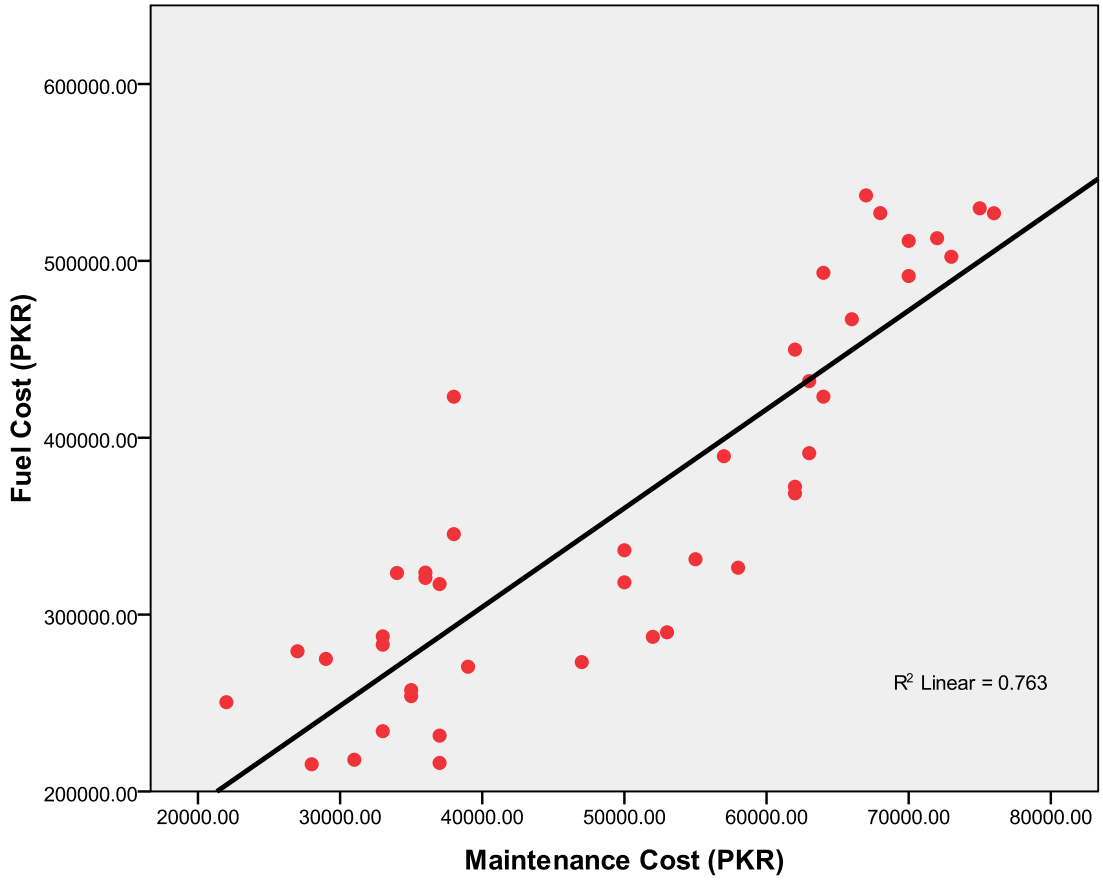

Figure 4: Correlation of fuel cost with maintenance cost.

Hence Pearson correlation and significance values lead to the rejection of null hypothesis and acceptanceof alternate hypothesis which states that

There is a significant, strong and positive correlation between fuel cost and other cost components including labour cost, consumables cost and maintenance cost, i.e. $r_1 \geq 0.50$; $r_2 \geq 0.50$; $r_3 \geq 0.50$ *and p-value* ≤ 0.01 *for all these correlations.*

There is a highly significant and very strong correlation of fuel cost with all other cost components including labour cost, consumables cost and maintenance cost but it does not reflect any causation between the tested variables. An increase in one of these costs also causes increase in the fuel cost and vice versa. The reason of high correlation between fuel cost and labour cost may be the overtime work hours resulting in more monthly fuel consumption. The workers need to be paid for these extra work hours resulting in high labour cost per month. The highly significant and very strong correlation between fuel cost and maintenance cost may be associated with depreciation phenomenon. Depreciated compressors and DTH drill machine(s) need frequent reactive and proactive maintenance works while these depreciated machines have low output efficiency thereby increasing the required operational time to complete a drilling activity. The reason for a highly significant and strong correlation between fuel cost and consumables cost may be due to the fact that the (button) bit becomes blunt after drilling to a certain length and needs sharpening. If such sharpened bit is further used for drilling activity, there will be slow penetration rate causing in additional work hours to get the job done which results in high fuel consumption and hence high fuel cost.

IV. Conclusion

The highly significant and very strong correlations among cost components incurred during bench drilling phase suggest that fuel cost is interrelated with other cost components and the operators and planners need more cautions to monitor the performance of drilling unit. Rise of an anomalous situation related to the drilling unit will not only increase one cost component but also induces an increase in the fuel cost too. Similarly more fuel consumption is a reflection of problems associated with the drilling unit which may result in increased work hours and maintenance activities which will eventually end up with high incurrence of other cost components.

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