Journal of International Conference Proceedings (JICP) Vol. 4 No. 3, 139-152, December, 2021
P-ISSN: 2622-0989/E-ISSN: 2621-993X
Https://www.ejournal.aibpm.org/index.php/JICP

KPI Assessment Using Business Process Analysis, Deterministic and Stochastic Monte Carlo Simulation. Case: KPI Fuel Ratio lt/bcm/km

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ARTICLE INFORMATION

Publication Information

Research Article

HOW TO CITE

Putra, G. A., & Mulyono, N. B. (2021). KPI Assessment Using Business Process Analysis, Deterministic and Stochastic Monte Carlo Simulation. Case: KPI Fuel Ratio lt/bcm/km. *Journal of International Conference Proceedings*, *4*(3), 139-152.

DOI:
https://doi.org/10.32535/jicp.v4i3.1305

Received: 12 November 2021
Accepted: 1 December
Published: 11 December 2021

ABSTRACT

The study investigates the basic behavior of Key Performance Indicator (KPI) Fuel Ratio (lt/bcm/km) which has created confusion among analysts and decision makers in a mining company by its anomaly in measuring fuel efficiency. This investigation is a part of a KPI Life Cycle which known as KPI Assessment phase to review if the KPI still has the capability to provide a good measurement. The method of this research is using combination of both qualitative and quantitative approach. Started with Business Process Analysis (BPA) approach to modelling current KPI formulation into a flow chart diagram with cause-effect technique. Then the results from BPA phase are validated through simulation analysis in both deterministic and stochastic Monte Carlo methods. To support the validation phase, actual operational data is collected from database. The results discovered that anomaly of this KPI was occurred because current formulation incorporating parameters that irrelevant with haul distance variable. Once the irrelevant parameters were eliminated from the calculation in the simulation experimentation, the anomaly of the KPI was disappeared. The findings of this research suggest that the KPI measurement required a new formulation to create a more reliable and robust tool to monitor the fuel efficiency.

Keywords: Business Process Analysis, Business Process Modelling, Deterministic Simulation, Fuel efficiency, KPI Assessment, Monte Carlo simulation, Parameter Relevancy

JEL Classification: M00, M10, M19

INTRODUCTION

Background

Siami-Irdermoosa and Dindarloo (2015) in their paper and a study to reduce fuel consumption in mining (Rodovalho, Lima, & Tomi, 2016) described that in mining industry, cost of fuel takes the largest composition of total mining cost. The success in monitoring the fuel efficiency will determine the success not only for the business but also for wider scope. The issue related to the fuel efficiency is not only in company-scale as mentioned. Over the past decade there has been a growing focus on energy management in the mining industry. It mainly caused by the rising energy costs in macro economy and the pressure to reduce gas emissions from fossil fuel use (Australian Government Department of Industry, Innovation and Science, 2016).

Currently most of mining company use Key Performance Indicator (KPI) Fuel Ratio (lt/bcm) to monitor the fuel efficiency performance (Australian Government Department of Resources, Energy and Tourism [DRET], 2014). This KPI compares total volume of fuel consumed for all equipment (liters) with total volume of overburden (OB) production (bcm) in a same period. The lower number of this KPI means the mining operation is more efficient in fuel consumption. KPI Fuel Ratio (lt/bcm) usually moves in the same direction with KPI Unit Cost ($USD/bcm). Both KPIs hold important part in assisting decision maker to see whether the mining operation is running in expected profitable way or it is not.

Complement to aforementioned KPIs, there is one additional KPI fuel ratio that has been created to monitor the fuel consumption efficiency relative to haul distance, KPI Fuel Ratio (lt/bcm/km). Basically, the KPI compares KPI Fuel Ratio (lt/bcm) with the average haul distance (km) in the same period. This KPI Fuel Ratio (lt/bcm/km) became one of important monitoring tools because haul distance (km) is also one of the main parameters to measure mining operation performance.

One of the strategies to make fuel consumption in mining operation more efficient is to have shorter cycle distance between loading point and dump point. If it is not sacrificing the future mine sequence planning, this strategy is arguably the most favorable strategy. It would cut the number of haul trucks requirement with the same OB production level. The result of this strategy is efficiency in mining operation indicated by lower KPI Fuel Ratio (lt/bcm) and KPI Unit Cost ($USD/bcm), assumed there are no negative changes in other parameters.

But this strategy will make a problem with the KPI Fuel Ratio (lt/bcm/km) measurement. When KPI Fuel Ratio (lt/bcm) indicates fuel efficiency, the KPI Fuel Ratio (lt/bcm/km) shows the opposite (see Figure 1). It will show significant higher number in shorter hauling distance and thus trigger the alarm for managements. A question then emerges, "We definitely succeed in the fuel consumption efficiency. But what happened with this KPI? was there anything wrong with the strategy? or the mistake was in the KPI measurement itself?

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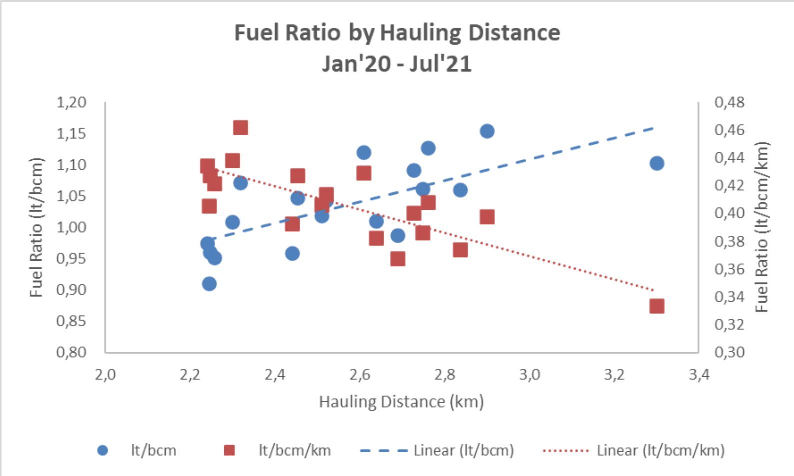
Figure 1. Actual Fuel Ratio Jan '20 to Jul '21 (Source: Internal Company)



Objective

The goal of this research is to understand the underlying behavior of KPI Fuel Ratio (lt/bcm/km). By understanding the behavior, an improvement in measurement and calculation process to create a more reliable and robust KPI can be proposed. The improvement hopefully will provide the business a more reliable tool to help reaching its goals.

To reach the objective, this research must be able to answer some questions:

1. If the haul distance is changed, what variable(s) that will also change? And what will not?
2. How is the movement of KPI Fuel Ratio (lt/bcm/km) in ceteris paribus condition where haul distance is the only changing variable while others are determined in ideal condition?
3. And how about the movement when uncertainty in all variables is incorporated? will it change the movement in ceteris paribus condition?

LITERATURE REVIEW

Key Performance Indicator Assessment

Choosing a Key Performance Indicator (KPI) to monitor a business process is a crucial step. Katuuk, Tewal, Massie, and Lengkong (2019) mentioned that the ability of the organization to clarify the measure plays a role in improving the quality of the implementation of the organization's strategies. Novitasari, Maharani, and Wardoy (2020) also mentioned that KPI as performance measurement has an important part to do as part of a strategy to achieve the expected goals.

A reliable and robust KPI will help decision makers at any level of management to make a good decision every time the KPI fall outside its reference point. A non-reliable will make the decision makers confuse instead because of the false alarm. A non-reliable KPI frequently being chosen without sufficient analysis to understand its underlying behavior and to understand which variables that relevant to the outcome of the KPI. A study to review KPI for process monitoring in mining industry (Gackowiec, Podobi´nska-Staniec, Brzychczy, Kühlbach, & Özver, 2020) described that since critical elements in process management in a company are process monitoring and control, it is therefore essential to choose KPI that are relevant to the monitored processes. DRET (2014) mentioned that KPI also must be able to be assessed continuously to monitor changes in the performance over time .

KPI Assessment is one of five cycles in KPI Life Cycle. This cycle is defined as the time when the KPI's stakeholders examines how relevant the KPIs are performing are how well it's been implemented. This cycle is an important part of the success of a KPI to bring the measured process directly to its goals. But, a study in performance management (Bourne, Mills, Wilcox, Neely, & Platts, 2000) mentioned that most of the practitioners only focus on the earlier phase of KPI development, designing the KPIs and not in implementing and updating phases.

Hester, Ezell, Collins, Horst, and Lawsure (2017) determined a method for KPI assessment which heavily rely on stakeholder involvement. The stakeholders are asked to score the KPIs that are being assessed in fourteen criteria adapted from Horst and Weiss's method, namely: quantifiable, relevant, predictive, standardize, verified, accurate, timely, traceable, independent, actionable, buy-in, understandable, documented, and inexpensive. The scores then are ranked based on the criteria weights. This process is similar with Analytical Hierarchy Process (AHP) method when making a complex decision. The result from this method is a list of assessed KPIs that sorted from the one that has poorest performance. The focus of the research is in characterizing a set of KPIs using subjective approach (stakeholder's justification) which may face human error risk (i.e., fatigue) while doing the scoring. The research also doesn't explain about the next step: the investigation to answer why these KPIs have the poor performance and what must be done with the KPI to make it works?

Bourne et al. (2000) defined the KPI assessment phase as 'updating processes.' This phase is described in a mini case where almost all update in the KPIs is based on the change of company strategy. The KPI will have annotations to highlight the update: (D) if it's deleted, (R) if it's replaced, (T) if it's having different target, and (M) if it's having different definition. The research also doesn't describe the detail process of the assessment that drives the KPI update.

KPI assessment is often an ad hoc and consultant-driven process rather than one undertaken using scientific principles (Hester et al., 2017). Thus, the process requires an enhancement by using more scientific-quantitative approach than a subjective-qualitative one. Also, it must have a deeper understanding on the process detail that is being measured.

Business Process Analysis
Wetzstein, Strauch, and Leymann (2009) in their study explained that Key Performance Indicator (KPI) is a performance measurement of a business process, which influenced by a set of Process Performance Metrics (PPMs) in smaller process units. There is Business Activity Monitoring (BAM), a part of Business Process Management (BPM) that provides useful information to analyst about the KPIs achievement. However, Wetzstein, Leitner, Rosenberg, Brandic, Dustdar, and Leymann (2009) mentioned that every time the KPIs underperform, BAM will only answer the analyst's 'what' question rather than 'why' question. The causes of the underperform KPIs are in one or more underperform PPMs which often undetected and rarely obvious to analysts and experts. To overcome the issue, Business Process Analysis must be conducted.

Business Process Analysis (BPA) is a method to review and understanding a whole process of a business or only in one specific part. It may involves reviewing the sequence of the processes, including inputs, procedures, and their interactions to produce outputs. One of the benefits from BPA is assisting the analyst to set the most proper KPI for the process and gain the knowledge how the KPI will behave in certain condition. To support the BPA, there is a method named Business Process Modelling that plays a major role in the perception and understanding the business processes. Koubarakis and

Plexousakis (2002) described in their paper that build a model may help to reveal anomalies, inconsistencies, inefficiencies and opportunities for improvement. As additional, Prasetyaningtyas, Maarif, Sobir, and Hermawan (2019) mentioned that process modelling also can be use to review business strategies and improve them.

According to Vergidis, Tiwari, and Majeed (2008), there are five types of Business Process Analysis: Observational, validation, verification, performance analysis and simulation. Those analysis types then can be matched out with three Business Process Modelling types: Diagrammatic, mathematical and Business Process Language.

Observational analysis type only can be approached using diagrammatic modelling and the quality of the result will be very subjective and heavily dependent upon the experience and knowledge of the analyst. Diagrammatic model is a qualitative model which according to Zakarian (2001), very unattractive and less meaningful as analysis tool. Van der Aalst and van Hee (1996) also has the same opinion: A simple diagrammatic model like Flowchart technique lacks in quantitative information that obstructs any further analysis and development of analysis methods and tools.

Quantitative approach only can be approached by using mathematical model which for this research may use the existing formulation to calculate the KPI Fuel Ratio. This approach can be combined with qualitative-diagrammatic model in observation analysis to create new form of flowchart with cause-effect model. This modified flowchart will cover up the disadvantage from using basic flowchart and answer the analyst’s need for more meaningful diagram model for further analysis, especially for this research.

Deterministic and Stochastic Monte Carlo Simulations

Van der Aalst (2007) mentioned that all models from BPA step are required to be validated using interactive simulation to test whether the process behaves as expected or to discover how it will behave in certain condition. The validation analysis can be done by interactive simulation: several fictitious cases are input to the model to see whether they are handled well as expected (Van der Aalst, 2007). Greasley (2003) said that the result from validation process through interactive simulation will help the decision makers to predict the performance of the process on different scenarios that they might be faced in the future. Wetzstein (2016) linked this validation analysis process with data mining that deals with the discovery of patterns from large amounts of data collected in log events.

Renard, Alcolea, & Ginsbourger (2013) mentioned that most of the simulations are mathematical model or quantitative. A mathematical model describes a process through a set of variables in equations that establish relationship between those variables. It divided into two major types: Deterministic and Stochastic.

A deterministic simulation is one where all variables are a single value determined by the analyst to see the result in one scenario only. Therefore, deterministic only has one unique solution. The limitation of deterministic simulation is that they do not account for uncertainty. Expand the deterministic simulation by adding randomness into one or all variables to incorporate uncertainty, there is stochastic simulation. The random variables are stated and described by probability distribution. Thus, stochastic simulation has many solutions, which allow the analyst to evaluate the inherent uncertainty of the natural system being simulated. Both simulations are not rival, these simulations are more and more applied nowadays in synergy rather than in competition and can be used at different stages of the same project (Renard et al., 2013).

RESEARCH METHOD

This study was carried out first by using a Diagrammatic Model in modified Flowchart Technique. The flowchart technique was modified using cause-effect technique that was brought from analyzing mathematical model of existed Fuel Ratio formulation used by mining industry. This first step is to analyze in a general view how change in input (haul distance) will affect the process in mining operation and the output (fuel ratio). In this step we will analyze which processes in mining operation are affected by the change of haul distance and which aren't. Processes that are not affected by the change of haul distance, thus considered as irrelevant parameters to KPI Fuel Ratio lt/bcm/km in the output. From this step we also set three modifications in the existed mathematical models to calculate Fuel Ratio. The difference between those three models is in how the irrelevant and relevant variables are treated in the mathematical model formulation. Those mathematical model formulations then will be compared in Deterministic and Stochastic Monte Carlo simulations.

Second, using above mentioned mathematical models to calculate Fuel Ratio, simulations in both Deterministic and Stochastic Monte Carlo are made to validate the analysis result in first step. In Deterministic simulations, all irrelevant parameters are determined in one single value, considered as ideal value for all scenarios while relevant parameters (haul distance and any parameters that interdependent to it) are changed once for every scenario. The result is a correlation graph between haul distance in x-axis and fuel ratio in y-axis.

Then a Stochastic Monte Carlo simulation is conducted. In this type of simulation, all relevant and irrelevant parameters are determined in a set of random numbers described by probability distribution from actual history data. The simulation is conducted for five thousand scenarios to achieve steady state parameters of a stochastic process with confident interval of 0.001. This confident interval approach was introduced by Suleman (1994) in his study to overcome problem when doing stochastic simulation without using specific software. Same as for Deterministic simulation, the result from Stochastic Monte Carlo simulation is a scatter correlation graph between haul distance in x-axis and fuel ratio in y-axis. The results from both simulations then used to analyze the behavior of KPI fuel ratio for every haul distance change and help to decide which measurement and calculation process that would give a robust and reliable KPI for every scenario.

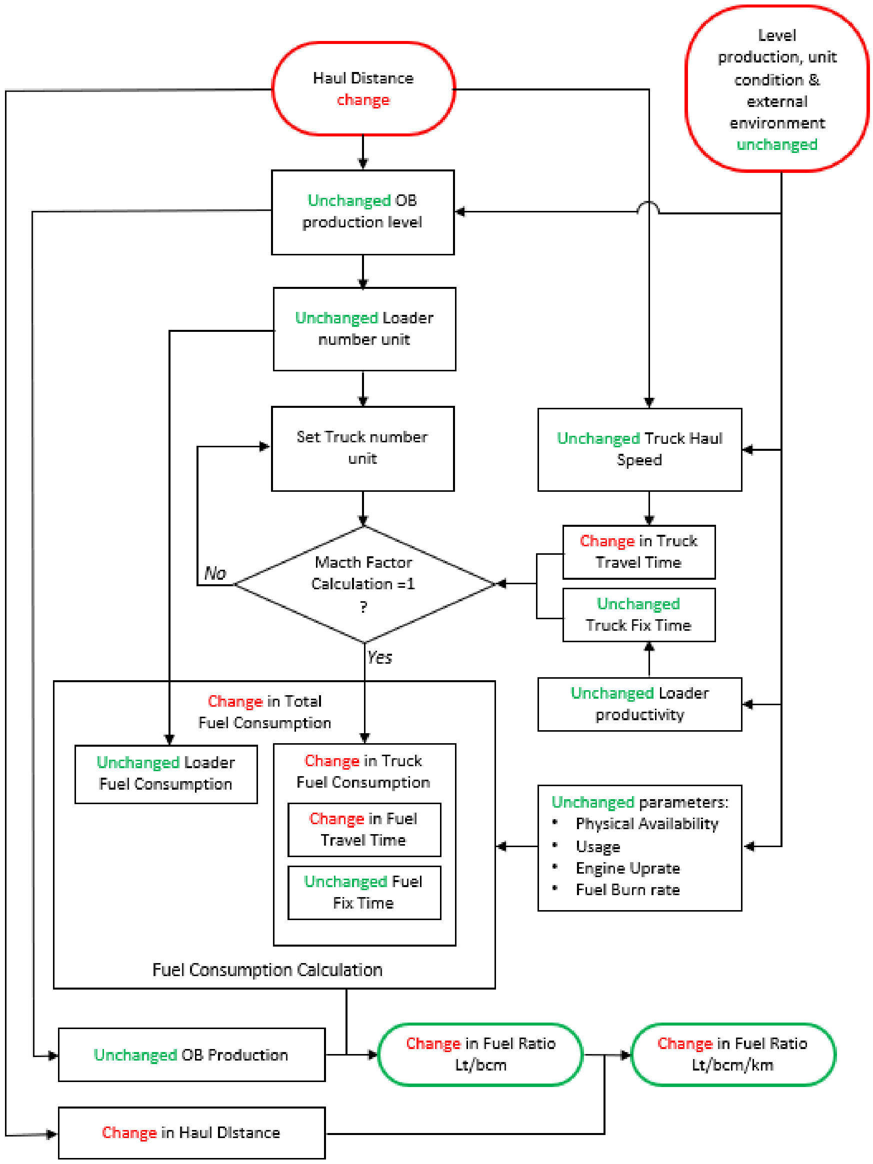
RESULTS

Business Process Analysis

Using Flowchart Technique that combined with Cause-Effect Technique in Diagrammatic Model, we could see in general view of how change in input (haul distance) affects the process in mining operation and the output (fuel ratio) as shown in Figure 5. This flowchart was built from brainstorming and analyzing the existed fuel consumption and OB production formula.

The analysis was started with assumptions that the basic parameter that allowed to change is just the haul distance while others like the production level (equipment productivity), equipment parameters (match factor, physical availability, usage, engine uprate and fuel burn rate) and the external environment parameters (road condition, material condition, people condition and weather condition) were unchanged.

Figure 2. Flowchart Diagram with Cause-Effect Analysis in Business Process



From the flowchart, we could see that KPI (lt/bcm/km) as the output of the process was also changed as the input (haul distance) changed. Then, if the KPI was separated into the next level of its variables, they have different effect status: Haul distance (km) was changed because of the analysis assumption and OB production (bcm) was unchanged also because of the analysis assumption. For the last variables, total fuel consumed (liters), it changed. Since the status of variables haul distance (km) and OB production (bcm) was set up from the assumptions, then the only one variable that required to have deeper analysis was the total fuel consumed (liters) variable.

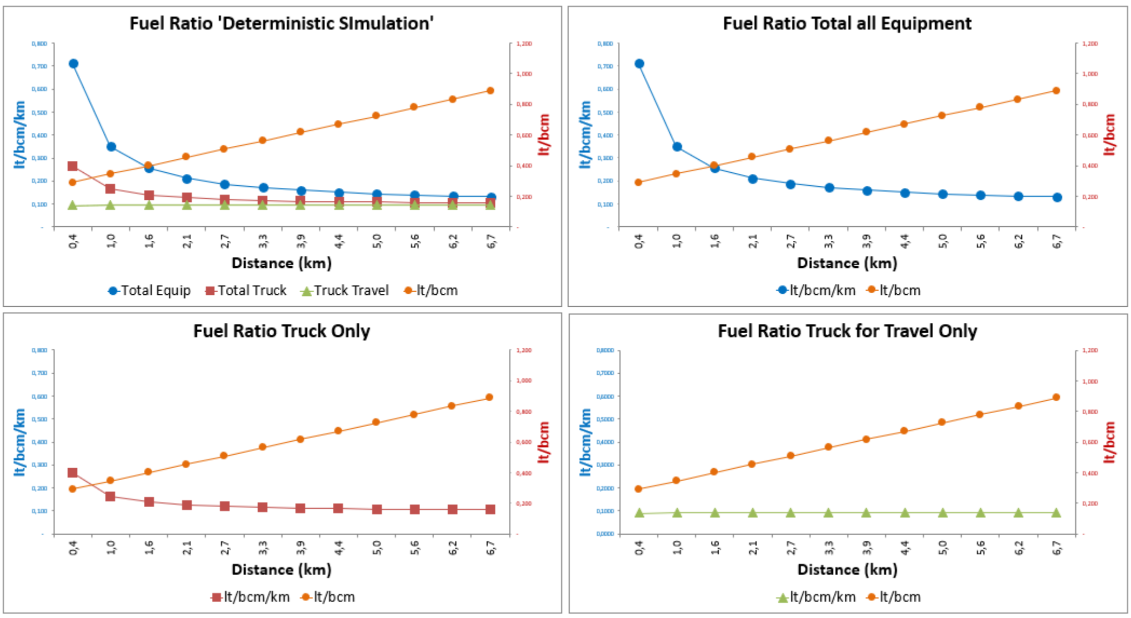
To have the detail analysis of fuel consumed (liters) variable, it required to be separated into the next level of its variables. From this, the fuel consumed (liters) has two variables: Fuel consumed by the loader and fuel consumed by trucks. Loader's fuel was unchanged because of the assumption of no change in OB level production so the number of the loader unit is unchanged. For Truck's fuel, it changed because unlike the loader, number unit of truck will change for different haul distance even in the same of OB level production. Until this step, it can be seen that total fuel consumption was a relevant variable to haul distance. But after it has been separated, truck's fuel consumption is the only relevant variable and loader's fuel consumption is not. New question then emerged, total fuel consumption variable is relevant to haul distance, but it still has irrelevant variable inside of it, the loader's fuel. So, is the truck's fuel having the same case? Does it have the hidden irrelevant variable inside of it?

Looking into the flowchart again, Truck unit has two main activities: Travel activity and fix activity. Travel activity is when the truck move from loading point area to disposal area and vice versa. While Fix activity is when the truck is loaded by the loader and when the truck disposed the material in disposal area. By discussion, haul distance only affects the travel activity, because the further the haul distance, the longer the travel activity takes time. While in fix activity, it will be the same for every haul distance. From that it can be concluded that truck's fuel consumption can be separated into its next level variables: Truck's fuel consumption for travel activity which is relevant to haul distance and truck's fuel consumption for fix activity which is irrelevant to haul distance.

Deterministic SImulation
In Deterministic simulation, we used existing Fuel Ratio (lt/bcm/km) mathematical model with a little twist in calculating fuel consumption (liter) following findings in Business Process Analysis. But for analysis concern, we did not do any change for Fuel Ratio (lt/bcm) mathematical model, since it must be calculated by using fuel consumption for all equipment to present the efficiency for whole process in the mining operation.

In this part, we have four charts showed the movement of Fuel Ratio (lt/bcm/km) in different haul distance (see Figure 3): Fuel Ratio for all equipment (top-right), Fuel Ratio for trucks unit only (bottom-left), Fuel Ratio for Travel Trucks only (bottom-right) and combined chart from all of them (top-left). The difference between these charts is in the fuel consumption (liter) parameter that used in the calculation. For all equipment, the parameter took fuel consumption from all equipment include the irrelevant parameter from loader fuel consumption. For trucks unit only, it excluded loader fuel consumption but still has irrelevant parameter from truck fix time fuel consumption. Last, for travel truck only, it only calculated relevant parameter from travel time fuel consumption.

Figure 3. Fuel Ratio Graphs from Deterministic Simulation



In Figure 3 top-right, we could see that if the haul distance decreased, the Fuel Ratio (lt/bcm) moved in the same direction. It showed us that there was efficiency in the fuel consumption for shorter haul distance. But in the opposite, the Fuel Ratio (lt/bcm/km) was exponentially increased. The shorter the distance, Fuel Ratio (lt/bcm/km) jumped significantly higher. This chart approximately formed a same shape with what we have for actual data in Figure 1.

When we use fuel consumption in trucks only in the calculation, Fuel Ratio (lt/bcm/km) still moved in opposite direction with Fuel Ratio (lt/bcm) but in more moderate way (Figure 3 bottom-left). But if we calculate only the fuel consumption for truck to travel, Fuel Ratio (lt/bcm/km) created a flat line graph which showed us that in every haul distance, this KPI will have a same number (Figure 3 bottom-right).

Stochastic Simulation

Deterministic simulation above conducted in Ceteris Paribus condition where only haul distance parameter is changed while others are determined in one single value, in this case we used the ideal value for budgeting purpose. Mining operation is a complex system where almost all parameters have the uncertainty. Thus, to enrich the analysis results from deterministic simulation and getting closer to the real system, a Stochastic Monte Carlo simulation was conducted.

First step to do in preparing this Stochastic Monte Carlo simulation was to set up the range of possible outcomes for some of irrelevant parameters. For relevant parameters, the randomness was only set up for truck unit number only since this number must be in whole number (discrete data). The haul distance then was calculated based the truck number unit with Match Factor (MF) equal to one (1).

There were three kinds of variable type: Constant variable to simplify the simulation as stated in research limitation, Random variable based on actual normal distribution (of daily data collected from January 2020, 1st until mid of 2021) and Random variable in discrete or whole number. For details see Table 1.

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P-ISSN: 2622-0989/E-ISSN: 2621-993X
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Table 1. Stochastic Parameter Data

					Random Variable				Constant Variable
					Random Between		Normal Distribution		
No	Variable	Variable Type		Unit	Bottom	Top	Mean	StDev	
1	Truck Number Unit	Relevant	Random	ea	3	15			
2	Digger Number Unit	Irrelevant	Constant	ea					1
3	Match Factor	Irrelevant	Constant						1
4	Road Grade	Irrelevant	Constant	%					0
5	Truck's Travel Speed	Irrelevant	Constant	km/hr					16,32
6	Truck's Payload	Irrelevant	Random	ton			279,5	26,2	
7	Digger's productivity	Irrelevant	Random	bcm/hr			1.968,6	75,3	
8	Truck's spot-load time	Irrelevant	Formula	min					
9	Truck's dumping time	Irrelevant	Random	min			1,8	0,2	
10	Truck's travel time	Relevant	Formula	min					
11	Truck's cycle time	Relevant	Formula	min					
12	Haul Distance	Relevant	Formula	km					
13	Equipment Availability	Irrelevant	Random	%			87,6	4,2	
14	Equipment Usage	Irrelevant	Random	%			62,0	13,6	
15	Engine Uprate	Irrelevant	Random	%			135,2	11,8	
16	Truck's Travel Fuel Burn Rate	Irrelevant	Constant	lt/hr					147,2
17	Trucks's Fix Fuel Burn rate	Irrelevant	Constant	lt/hr					116,0
18	Truck's Fuel Burn rate	Irrelevant	Formula	lt/hr					
19	Digger's Fuel Burn rate	Irrelevant	Random	lt/hr			402,8	30,8	

This stochastic simulation process was not conducted in a specific simulation software but in Microsoft Excel only. The only reason is, by using Microsoft Excel we can check the detail of each random parameter number in a particular scenario for deep analysis purpose. But it has a drawback, Microsoft Excel did not have the ability to stop the simulation process until it reaches the steady state condition. To overcome this problem, we must manually set the steady state condition where we have enough number of scenarios sample that has a reliable result close to the true population mean. One technique to set the steady state manually is using confidence interval approach as a measurement of Level of Precision. Level of precision is the maximum degree the true population mean can deviate from the sample mean estimation, subject to a given confidence level.

To do it, first we determined our desired level of precision, in this case we set it to 0.001. Second, we set the confidence level to 95% (z = 1.96). Third, to get standard deviation from sample, we initiated the first simulation for 1,000 scenarios and from that we got standard deviation of 0.036.

$$z = \frac{\emptyset}{s/\sqrt{n}}$$

Where:

z = Confidence level
Ø = Level of precision
s = Standard deviation from sample
n = Number of simulation scenario

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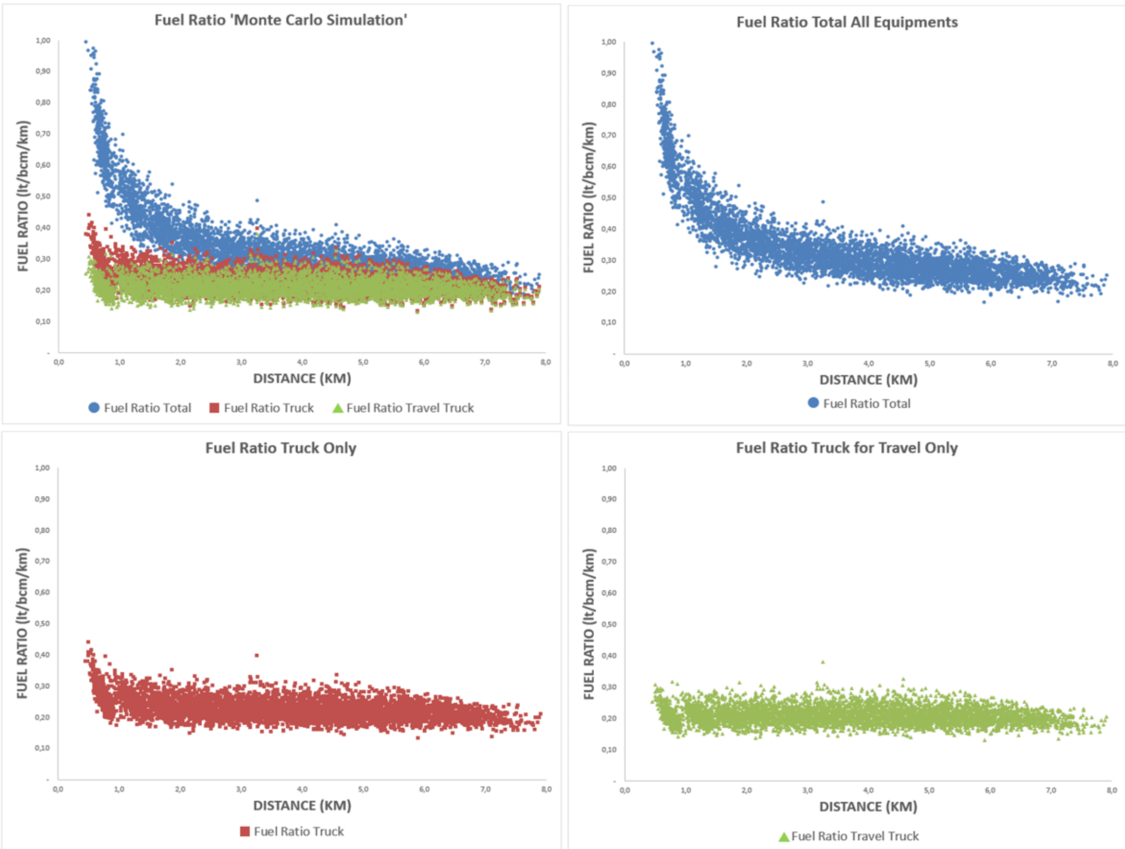
By using above formula and known variables, we could solve the n

$$1{,}96 = \frac{0.001}{0.036/\sqrt{n}}$$

$$n = 4{,}884$$

Therefore, to make the stochastic Monte Carlo simulation has reliable results within the level of precision, we must run it for around 5,000 scenario simulations. The result from this stochastic Monte Carlo simulation is presented in Figure 4 below. On the top-left side is the combination from three graphs: Fuel Ratio for all equipment, Fuel Ratio for trucks unit only and Fuel Ratio for Travel Trucks only. For clearer view like we had on deterministic simulation results, Figure 4 also shows graphs for each one. From this we can see that there were no differences in shape between the result from stochastic and deterministic simulations.

Figure 4. Fuel Ratio from Monte Carlo simulation



DISCUSSION

What makes Fuel Ratio (lt/bcm/km) increases in shorter haul distance, opposite to Fuel Ratio (lt/bcm) for current formulation? The answer is because the current KPI Fuel Ratio (lt/bcm/km) formulation also calculates parameters that irrelevant or doesn't have correlation with the haul distance. The only parameter that has relationship with the haul distance is only the total fuel consumed for truck to travel, which drove by the change in truck unit number requirement to keep the ideal Match Factor with the loader. Others, like fuel consumed for truck in fix time: spot-load time and dumping time in ideal condition will be the same for every distance. So does the fuel consumed for loaders, it doesn't get affected by the change from haul distance for the same level of OB production.

Deterministic simulation confirmed the answer. That is why if we only calculate the total fuel consumed for truck to travel, the only relevant parameter to haul distance, we will have a single number KPI for every haul distance as shown in Figure 3 bottom-right. Adding fuel consumed for truck in fix time and fuel consumed by the loader into the current KPI formulation will make it jump in exponentially-like behavior in shorter haul distance (Figure 3 top-right). This behavior can be explained by basic mathematic process. KPI Fuel Ratio (lt/bcm/km) is basically a division between parameter Fuel Ratio (lt/bcm) as numerator and parameter haul distance (km) as denominator. Looking up into simulation data in Table 2 below, if the haul distance decreased 17.5% from 3.29 km to 2.71 km, the Truck's fuel consumption to travel will also decrease 17.5%. But for Total Truck's fuel consumption, it will only decrease 14.3% because it still has the variable fuel consumption for fix activity which will always be in constant level for every haul distance. Same case for total fuel consumption, it will only decrease 9.6% because it has not only variable truck's fuel consumption for fix activity but also the loader's fuel consumption variable which also in constant number for every haul distance.

This gap will be getting larger in shorter haul distance. For example, if the haul distance got shorter from 0,98 km to 0,41 km or decreased 58.4%, the Truck's fuel consumption to travel will also decrease 58,4%. But for total fuel consumption, it will only decrease 15.7%. This 42.7% gap between the numerator and denominator created a huge jump of Fuel Ratio (lt/bcm/km) for total all equipment from 0,351 to 0,712 lt/bcm/km.

Table 2. Deterministic Simulation Data

Haul Dist. (km)	Fuel Consumed (liters)			Drop Rate (%)			
	All Equip.	Truck Only	Truck to Travel	Haul Dist. (km)	All Equip.	Truck Only	Truck to Travel
0,41	14.679	5.463	1.941	58,4%	15,7%	33,3%	58,4%
0,98	17.410	8.194	4.672	36,9%	13,6%	25,0%	36,9%
1,56	20.141	10.925	7.404	26,9%	11,9%	20,0%	26,9%
2,14	22.873	13.657	10.135	21,2%	10,7%	16,7%	21,2%
2,71	25.604	16.388	12.866	17,5%	9,6%	14,3%	17,5%
3,29	28.336	19.120	15.597	14,9%	8,8%	12,5%	14,9%
3,86	31.067	21.851	18.329	13,0%	8,1%	11,1%	13,0%
4,44	33.798	24.582	21.060	11,5%	7,5%	10,0%	11,5%
5,01	36.530	27.314	23.791	10,3%	7,0%	9,1%	10,3%
5,59	39.261	30.045	26.523	9,3%	6,5%	8,3%	9,3%
6,16	41.992	32.776	29.254	8,5%	6,1%	7,7%	8,5%
6,74	44.724	35.508	31.985				

The results we got from Stochastic Monte Carlo simulation strengthen the confirmation. Even after we included the uncertainties into the calculation and used 5,000 different scenarios, the results have no differences.

CONCLUSION

From this research we can make a conclusion that current KPI Fuel Ratio (lt/bcm/km) formulation has a big flaw. It calculates irrelevant parameters that creates anomaly in the result and may confuses the analyst and decision makers. Since this KPI focuses heavily on fuel efficiency related to haul distance, then the only parameter that must be measured and calculated is fuel consumed for truck to travel. Not the fuel consumed by the loader nor for truck in fix time activities. Fuel consumed for truck to travel will always be move in the same direction and has positive correlation with haul distance. But not with fuel consumed by the loader and for truck in fix time activities, they don't have correlation because they will be remaining the same for any haul distance.

It has similar concept with fixed cost and variable cost in managerial accounting. We call it fixed cost because it remains the same for any level of output and otherwise for variable cost. It would be very confusing and 'controversial' to calculates fixed cost per unit output because it is not relevant with the level of production (Suleman, 1994).

So, it is important to understand first any KPI that we want to use. What is the purpose? What parameters that must be included or excluded in the measurement? How will it behave in the determined or in uncertain conditions? By answering that, hopefully we could have KPI that is not only reliable but also robust in every condition that could give us or any analyst and decision maker a very insightful information without worrying the false-alarm risk

LIMITATION

To simplify this research, business process analysis and simulations were conducted for one type of digger and truck only. Support unit like dozer, grader and others will be taken out from the calculation. Also, road grade is assumed 0% flat.

ACKNOWLEDGMENT

The author would like to thank his advisor and co-author, Nur Budi Mulyono from School of Business Management, Bandung Institute of Technology, for his support and encouragement on this research. The author also thanks all the colleagues from several mining company who shared the data and the insight about the issue.

DECLARATION OF CONFLICTING INTERESTS

The author declares that there is no conflict of interest, financially or non-financially related to this research.

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