Procurement Strategy and Supply Risk Analysis of Coal By Considering Price Fluctuation and Supplier Delivery Time

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Abstract

Under price uncertainty, the decision on how long a supply contract for a certain commodity should be, is an important question a decision maker has to address. The length of supply contract will affect both the financial aspect as well as the risks. This research will discuss about the selection of 3 (three) procurement strategies namely long-term procurement strategy, short-term procurement strategy, and mixed strategy by considering uncertainty factors such as commodity price, supplier delivery time and quality in which the three factors are considered to be uncertain. We compare the benefits, costs and risks associated with each strategy. We use the Monte Carlo Simulation method to represent the level of uncertainty of all variables. Cost-Benefit Analysis is used to calculate the economic aspects while the procurement supply risk analysis is used to determine the risk associated with each strategy. The results show that the mixed strategy of 24-month and 6-month outperformed other strategies.

Keywords
Procurement, Procurement Strategy, Monte Carlo Simulation, Cost-Benefit Analysis, Risk Analysis

1. Introduction

With the uncertainty in commodity prices, an important question to address is whether a company will sign a supply contract for a longer term or for a shorter term. Each could be associated with financial as well as risk consequences. Long-term procurement with a single supplier has several advantages, for example, if a pure decision is made due to cost considerations, working with one supplier may be more preferable as it can minimize costs arising from uncertainty and suppliers have the potential to provide cheaper prices because the sale is assured (Peleg et al., 2002). With long-term contracts, the average price may be lower than the short-term contract, and is more stable but less flexible (Inderfurth & Kelle, 2011). Several studies have discussed the procurement strategy. Peleg et al. (2002) compares the use of short-term procurement in the form of strategic partnerships, short-term procurement in the form of online search and combined both. Kleindorfer & Wu (2003) studied channel coordination by integrating long-term contracting and short-term contracting within the Business-to-Business (B2B) framework in solid industries capital (capital-intensive industries).

The choice of procurement strategy that will be used by companies other than determined by commodity type is also determined by several variables. Peleg et al. (2002) stated that generally procurement decisions are influenced by several things such as delivery time, price and quality. In the case of procurement of commodities with large quantities (volume or tonnage), sea transportation is the most appropriate mode of transportation given the ability to transport large quantities of goods / commodities on a single trip, for example coal, raw materials, fertilizers and other goods in bulk form. With regard to the use of sea transport in this delivery, there is certainly a lot of uncertainty that can be a risk for both the seller and the buyer. For example, port congestion density and sea-weather changes may result in delays in delivery of goods to the destination of the buyer. This is a risk for the buyer that the possibility of shortage of inventory which can lead to decreased of production levels or even the termination of factory activity due to the absence of raw materials.

In terms of price, goods / commodities that are vulnerable to price changes are also a separate risk in the problem of procurement strategy selection. Prices that often change to follow the development of world market prices certainly affect the business processes for both sellers and buyers. Buyers are likely to buy more at a time when prices are declining in order to gain a lower unit cost advantage and large volume / quantity of purchases. While on the other hand the seller will tend to hold the goods not to sell if the price trend is decreasing to cover operational costs and avoid greater losses.

Quality becomes one of the important variables that influence the decision of procurement strategy. Consistent quality of goods / commodities can support the smooth production process of a factory. It is easy to manage if the goods / commodities used as raw materials are manufactured / manufactured goods, and will become difficult when goods / commodities are not manufactured by manufacturers, such as mining products such as petroleum, coal, and natural gases. Goods / commodities like this are certainly vulnerable to quality fluctuations where the quality of goods supplied by one source could be different from that obtained from other sources. Therefore, the buyer in this case need to find the right strategy to anticipate the change of the three variables in order to achieve the target of the right procurement price, the right quality, the timely supply as well as the preservation of supply continuity in order to support the production process.

This study is an attempt to evaluate different supply contract terms under the situation of price uncertainty, quality fluctuation, and supply lead time consideration. We compared three strategies, short-term contract, long-term contract, and a mixed between long-term and short-term contract. The short-term contract is for the duration of 3, 4, and 6 months. The long-term contract is for the duration of 12, 24, and 36 months. The mixed strategies are 9 combinations which will be defined in a later section. The three alternative strategies are compared in terms of financial performance as well as in terms of risks. The study is based on the case of coal procurement in a company producing fertilizer in Indonesia.

2. Literature Review

2.1 Variables that affect the procurement process

In the procurement process there are several variables that affect its performance. In general, the procurement decision-making process is influenced by several things such as the delivery time, price and quality Peleg et al. (2002). Hong & Lee (2013) in his research mentioned three factors namely the number of demand, spot price and production *uncertainty*. De Toni and Nassimbeni (1999) in Talluri & Lee (2010) cites some of the fundamental factors considered in the procurement strategy of which suppliers to choose, the number of suppliers to be used and the length of the contract. Luo et al. (2015) developed the decision model supply chain coordination uses two sources of procurement of the real contract and spot market options by considering the variable demand, price and risk on the spot market.

Inderfurth & Kelle (2011) in his study also analyzed the impact of the uncertainty of demand and price with a capacity reservation procurement strategy. Slightly different from the above research, besides the variable of demand and price, Kleindorfer & Wu (2003) also consider other important variables in the procurement process i.e., order quantity. While Peleg et al. (2002) consider the variable number of suppliers, quantity of ordering / purchase and pricing in their research on comparisons of the use of strategic partnerships and online searching. Selection of procurement strategy between online spot market with long-term contracts are also affected by the demand, spot price volatility, the correlation of the number of requests and the spot price and a tendency to avoid risk (risk aversion) on top of that has been used by some previous research. Table 1 lists the factors considered and the associated authors.

Table 1. Table of variables / factors that influence the procurement process

Variable / Factor	Authors
Price	Peleg et al. (2002), Kleindorfer & Wu (2003), Seifert et al. (2004), Inderfurth & Kelle (2011), Hong & Lee (2013), Luo et al. (2015)
Demand	Kleindorfer & Wu (2003), Seifert et al. (2004), Inderfurth & Kelle (2011), Hong & Lee (2013) , Luo et al. (2015)
Yield uncertainty	Hong & Lee (2013)
Number of Supplier	Peleg et al. (2002), De Toni and Nassimbeni (1999)
Contract Duration	De Toni and Nassimbeni (1999)
Risk	Seifert et al. (2004), Luo et al. (2015)
Order quantity	Peleg et al. (2002), Kleindorfer & Wu (2003)

2.2 Procurement Strategy

The selection of an appropriate procurement strategy for a company plays an important role in the success of a procurement process. One of the strategies is related to the length of supply contract. The choice of procurement contract type becomes a critical decision faced by the company (Talluri & Lee, 2010). There are basically two types of procurement strategy: long-term procurement and short-term procurement, however in some studies there is a combination of these two strategies to a mixed strategy.

Long-term procurement is generally more strategic and crucial for companies, especially for goods / services that are routine needs and become a major part of a company's production process, while short-term procurement is generally reserved for non-routine but necessary needs. Long-term procurement is usually done with one or a few number of suppliers. By implementing long-term procurement strategy, the company has several advantages that can reduce the cost / price uncertainty and can provide incentives for suppliers to provide lower prices to secure / ensure the sustainability of its sale (Peleg et al., 2002). Another advantage is to avoid companies / buyers from risks of price increases (Inderfurth & Kelle, 2011). Long term procurement strategy can also provide price stability for the company, but on the other hand has a low level of flexibility (Inderfurth & Kelle, 2011). In addition to its advantages, long-term procurement strategy also has a weakness that is the risk of yield uncertainty and the amount of demand (Hong & Lee, 2013).

Short-term procurement strategies have an advantage in their application, which is high flexibility, but on the other hand has a high price rising risk (Inderfurth & Kelle, 2011). Short-term procurement is usually not tied to prices and tends to be easier to perform, compared to long-term procurement. However, short-term procurement also does not escape deficiencies, where prices are usually higher than prices obtained from long-term procurement strategies (Hong & Lee, 2013). Short-term procurement strategies in the form of online spot markets offer negligible lead times and high flexibility, but they must be paid at normally higher rates and tend to be uncertain (Seifert et al., 2004).

Several studies have been conducted by some researchers on the combination of long-term procurement strategies and short-term procurement. Luo et al. (2015) define the mixed procurement strategy optimized by integrating the use of real-options contracts and the spot market. Inderfurth & Kelle (2011) studied the combination of the use of 2 (two) alternative procurement strategies namely capacity reservation contracts and spot markets against the use of single source of procurement.

Peleg et al. (2002) compares the use of 3 (three) procurement strategies i.e., long - term procurement strategy in the form of strategic partnership and short-term procurement strategy in the form of online search, and a combination of both. In addition, in this study also analyzed the exact number of suppliers and how it is influenced by the parameters of the demand and price. Kleindorfer & Wu (2003) integrate the long-term procurement strategy and the provision of short-term on the scheme Business-to-Business (B2B) for capital-intensive industries.

2.3 Coal Business Trends

Indonesia is one of the coal producing countries in the world. According to *Statistical Review of World Energy 2016* released by British Petroleum (BP), until the end of 2015, Indonesia has proven reserves of 28.017 billion tons of coal which is equivalent to 3.1% of the world's proven coal reserves. In terms of production, Indonesia recorded 241.1 million tons of coal in 2015 or 6.3% of the world's total coal production. In terms of consumption, Indonesia recorded a 15 percent increase from 69.8 million tons in 2014 to 80.3 million tons in 2015, equivalent to 2.1 percent of the world's total coal consumption.

Coal prices in recent years have also declined as consumption declines globally. For example, Asia's benchmark *Asian Marker Price has* recorded a downward trend in coal prices since 2012 through 2015, where the 2012 price of USD 105.5 drops to USD 63.52 by 2015 (British Petroleum, 2016).

In the business of coal in Indonesia, there are two types of coal sales method, namely direct selling ("*spot*") and contract for a certain term ("*term*"). Direct selling (*spot*) is a sale where the time period is less than 12 months and the price of coal used should refer to the Reference Coal Price in the month in which the coal is delivered. While certain term sales are coal sales with maturities of 12 months or more and the price used refers to the last three months of the reference price where the coal price agreement takes place (Regulation of the Minister of Energy and Mineral Resources No. 17 of 2010).

2.4 Supply Risk Analysis

Every activity is always associated with *uncertainty*. Merrett and Sykes (1983) in Merna & Al-thani (2008) suggest that uncertainty arises when there is more than one possible outcome for an action but the probability of each action is unknown. According to Frank Knight (1965) in Zsidisin & Ritchie (2008) uncertainty is an event or phenomenon that can not be measured, while the risk is measurable events. Zsidisin (2003) defines supply chain risk as a potential occurrence of an event related to inbound supply activities that may result in the inability of the company as a purchasing organization to meet customer demand (Dani (2008) in (Zsidisin & Ritchie (2008)). Tang & Tomlin (2008) in Zsidisin & Ritchie (2008) categorize supply chain risks into 5 (five) based on the area where the risk may occur. These are supply risks, process risks, demand risks, rare-but-severe disruption risks, other risks. Supply Chain Risk Leadership Council categorizes potential risks for an organization or company and its supply chain network in 4 (four) categories, namely external, end to end risk, supplier risk, distribution risk, and Internal enterprise risk where each category has several sub-categories that are risk factors that may occur in a supply chain (SCRLC, 2011).

Risks in a supply chain need to be well managed to avoid both material and immaterial losses, including procurement activities as one of the main activities in supply chain management. (Pujawan & Geraldin, 2009) proposed a model called House of Risk (HOR) to proactively handle the supply chain risks. Nagali et al (2008) in Hong & Lee (2013) states the procurement risk management is crucial in the success of supply management. As described before, a company or organization can meet its needs by 2 (two) ways of making your own materials / components needed (produce / make) or buy / get from parties outside the company (outsourced). The use of outsourced steps from outside the company or supplier began to be popular since the 1980s, where many of the companies did it for products that were not their core competencies (Hong & Lee, 2013). Therefore, it is very important to know and manage these procurement risks, due to the procurement function that is vital to the company and the value and volume of procurement each year.

The first step required of supply chain risk management aspects of risk identification and risk factors of a supply chain. Supply risks as described by Tang & Tomlin (2008) in Zsidisin & Ritchie (2008) consist of 3 (three) risks:

1. Supply cost risk.
   The risk of the price per unit of goods paid by acquirers that can fluctuate from time to time, which may be caused by changes in the price of raw materials and exchange rates.
2. Supply commitment risk.
   The commitment that occurs between the seller and the buyer can be a risk for both the buyer and the supplier. For example, fixed and binding fixed-term contract commitments in terms of quantity and price of goods may make it difficult for either party to change the level of demand or unpredictable raw material prices or due to changes in market conditions that are outside reach of each party.
3. Supply Continuity Risk.
   Continuity of supply becomes an important issue in supply chain management. Supply continuity provides assurance of the availability of raw materials and the sustainability of a product's production process. Disruption of supply continuity will cause production problems that potentially disrupt supply smoothness in the downstream side of a supply chain that is the final consumer.

3. Research Methodology

In this research, 3 (three) general procurement strategies are evaluated, namely short term strategy (ST) strategy, long term strategy (LT), and procurement strategy of mixed long term and short term strategy (MT). The three strategic groups are outlined based on procurement time as shown in Figure 2. The 3 month short term procurement strategy (ST-3) is an existing strategy currently used by the company, while other strategies are alternative strategies that will be compared with existing strategies. Each strategy will be evaluated by calculating the benefits and cost and risk by considering the uncertainty of 3 (three) variables namely price, delivery time and quality, with Monte Carlo simulation approach.

In this section, we described the methodology and sequence of construction steps of research that began with the coal procurement business process mapping, data collection, data processing which is divided into two phases, namely a simulation study variables using Monte Carlo simulation and analysis of costs and benefits and risk analysis of procurement. In Phase 1, will be a simulation of the variables considered is the uncertainty in determining the procurement strategy is appropriate that fluctuations in the price, supplier delivery time, and quality for each of the initial strategy using Monte Carlo simulation. It aims to get the pattern of randomness which describes the uncertainty of these variables in real systems.

In Phase 2, will be conducted cost analysis and benefits of each alternative procurement strategies using Cost-Benefit Analysis (CBA) taking into account the results of each simulation initial strategy to variable price, supplier delivery time, and quality. Then, risk analysis is used to know the risk category contained from each procurement strategy and its risk value.

After obtaining Net Present Value (NPV) value and risk value of each strategy, then summarize NPV value and risk value. The NPV value and the risk value of each strategy are aggregated to obtain an end value reflecting the cost-benefit and risk values of each strategy. The best procurement strategy will be selected based on the highest end value.

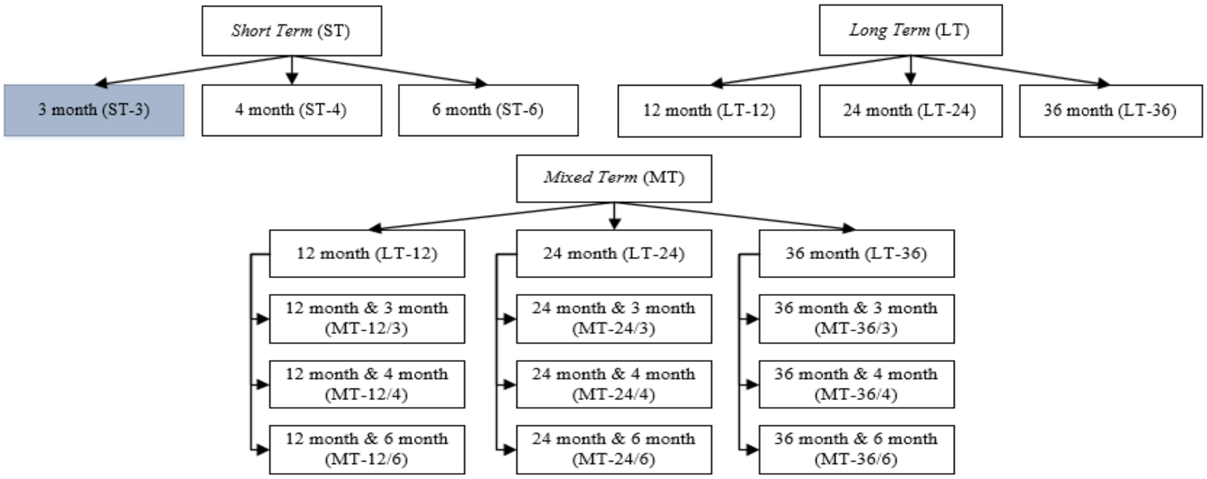

Figure 2. The three strategies related to coal procurement contract

4. Case Study

4.1 Data Collection

The integration of the method was applied in a fertilizer and agrochemical company as a coal user for steam fuels. The company currently has 5 plants that produce urea and ammonia, 1 plant producing NPK, and 1 coal boiler plant which uses coal as fuel. Coal Boiler Factory is a factory that has a very important role because this plant supplies the needs of steam which is used for fertilizer production process. The following is a summary of the data used in this study.

Table 2 Price data, delivery time and coal quality.

PO Code	Price (Rp/ton)	Delivery time (day)	Quality Parameters		
			Calorific Value (kcal/kg)	*Ash Content* (%)	*Sulfur* (%)
53001	709,289.80	2	5,560	4.9	0.18
53002	681,801.54	3	5,325	4.4	0.19
53003	667,130.56	2	5,507	4.5	0.24
53004	576,795.32	5	5.103	5.7	0.7
53005	649,095.86	1	5,481	6.4	0.43
53006	649,095.86	1	5,481	6.4	0.43
53007	649,095.86	1	5,481	6.4	0.43
53008	789,157.55	1	5,335	5.5	0.47
53009	704,540.24	5	4,316	2.97	0.1
53010	708,268.08	2	4.175	3.9	0.37
53011	656.266.58	2	4,151	3.54	0.36
53012	913,620.20	1	5.339	5.5	0.39
53013	913,192.26	2	5.258	3.97	0.34
53014	877,810.83	2	5,298	3.76	0.31
53015	875,501.52	1	5,432	5.3	0.45

4.2 Monte Carlo Simulation

The simulation model is basically divided into 2 (two) i.e., simulation that is deterministic and probabilistic simulation. One of the most commonly used probabilistic simulation methods is the Monte Carlo simulation. Monte Carlo simulation is a type of probabilistic estimates of simulation solutions to a problem with the sampling of a random process (Tersine, 1994). The Monte Carlo simulation is a computer-based probability simulation used to determine the impact of the uncertainty of an approximate model (Mahdiyar et al., 2016).

Monte Carlo simulation method has been widely used in various studies and research. In relation to procurement risk management (PRM), Hong & Lee (2013) builds an algorithm model to quantify the risk of each supplier for decision makers to know the trade-off between risk and profit. The study proposes a Monte Carlo-based simulation algorithm called Expected Profit-Supply at Risk (A-EPSaR) combined with Goal Programming to determine the allocation of orders between the supplier pool and the contract-spot allocation model establishing the order between the spot market and the supplier pool. Mahdiyar et al. (2016) uses Monte Carlo simulations to model the uncertainties of the Net Present Value (NPV) and Payback Period ranges in green roof application issues.

In this study we have calculated the results for each strategy the price per ton, the delivery time, as well as the quality parameters. Table 3 presents the results.

Table 3 Summary of simulation results.

Strategy	Price (Rp/ton)	Delivery time (day)	Quality Parameters		
			Calorific Value (kcal/kg)	*Ash Content* (%)	*Sulfur* (%)
ST-3	702,533.76	2.00	5342.24	4.891	0.375
ST-4	699,536.59	2.01	5345.09	4.889	0.378
ST-6	699,964.75	2.04	5399.17	4.910	0.384
LT-12	680,411.78	2.1	5414.83	4.900	0.392
LT-24	678,128.22	2.16	5417.68	4.852	0.395
LT-36	677,842.78	2.18	5419.1	4.851	0.395
MT-12/3	693,827.69	2.06	5377.11	4.892	0.384
MT-12/4	693,185.44	2.06	5387.08	4.895	0.386
MT-12/6	686,192.04	2.07	5405.58	4.894	0.389
MT-24/3	690,901.88	2.09	5372.13	4.872	0.385
MT-24/4	689,403.29	2.09	5394.9	4.874	0.387
MT-24/6	684,051.20	2.1	5409.85	4.887	0.390
MT-36/3	692,685.91	2.09	5376.4	4.852	0.385
MT-36/4	687,405.18	2.1	5380.67	4.857	0.387
MT-36/6	683,694.40	2.11	5408.43	4.867	0.390

Through the Table 3 can be seen that in general the longer the procurement strategy period will be the lower the price of coal simulation results. This is in accordance with the principle that the longer the purchase period and the more quantity of purchase, the price will be more competitive from the buyer side, which means the investment / purchase cost incurred by the company is getting lower.

For the delivery time variable, according to the above table it is known that the longer duration of the procurement strategy will be the higher / longer delivery time of simulated coal. This is inversely proportional to the linear price of coal with the length of time that coal is procured. This is possible because the longer the procurement period in one order it will be more quantity ordered so that require shipment arrangement more complex and takes longer both for supplier in arranging shipment schedule and for buyer in managing the process of ship berthing and receiving at the port of unloading.

The lowest calorific value of the 3-month short term procurement strategy (ST-3) and the highest in the 36 month long term procurement strategy (LT-36) with consecutive values of 5342.24 kcal / kg and 5419.1 kcal / kg. In general there is a trend of increase in value of coal calorific value of the procurement strategy used. Based on the simulation results, calorific value will be higher if the procurement strategy used longer. This means that the longer the procurement period / time will be the better the quality of coal obtained and the more efficient use of coal in the steam production process.

The lowest content of ash content based on the simulation result is 36 month long procurement strategy (LT-36) with value 4,851%, while the highest is the 6 month long term procurement strategy (ST-6) with 4,910%. In general there is a decrease in ash content, where ash content is increasing in short-term procurement strategy (ST) and mixed procurement strategy (MT), but tends to decrease in long-term procurement strategy. However, in general there is a downward trend in line with the longer duration of the procurement period. This means the longer the procurement period / time used will be the better the quality of coal obtained due to impurities in the form of ash content (ash content is smaller, so the cost of processing solid waste becomes lower).

The lowest sulfur content based on the simulation result is a 3 month short term procurement strategy (ST-3) with a value of 0.375%, while the highest is a 36 month long procurement strategy (LT-36) with a value of 0.395%. Through the table above, it is known that the content of sulfur content increases with the length of time duration /

period of procurement used. This means that the longer the procurement period used then the quality of coal obtained will decrease due to impurities in the form of sulfur content is higher and can cause the cost of processing waste becomes higher.

4.3 Cost-Benefit Analysis

Cost-Benefit Analysis (CBA) aims to provide consistent procedures in evaluating decisions regarding its consequences (Dreze & Stern, 1987). Cost-Benefit Analysis (CBA) has been used in many studies, such as by Liu et al. (2014) who studied the benefits and costs on a case study of alternative purchase or leasing 4 KW solar PV panels in California, USA. While Battistoni et al. (2016) conducted a study on Cost-Benefit Analysis on research infrastructure with case studies carried out in the health sector. Research by using Cost-Benefit Analysis method was also conducted by Mahdiyar et al. (2016), where they integrate Cost-Benefit Analysis with Monte Carlo Simulation to identify investment aspects of green roof installation.

Cost-Benefit Analysis is an economic analysis that takes into account 2 (two) components namely Cost and Benefit. In the procurement problem, there are some variable / cost component and benefit considered. In this study, we developed a scheme of costs and benefits of coal use taking into account actual conditions and industry characteristics in the field, resulting in cost component schemes and benefits such as the following table:

Table 4. Components of benefits (benefits) and cost of coal procurement.

Aspect	Component	Notation	Formula
Benefit	Steam price	*S*	$S = \left(\frac{VC}{Q}\right) + FC$
	Increased productivity	*Q*	$\Delta Q = (Q_i - Q_0)\ x\ S$
	Inventory cost reduction	*I*	$\Delta I = I_i - I_0$
	Labor cost reduction	*W*	$\Delta W = W_i - W_0$
Cost	Investment cost / purchase of coal	*P*	*Coal Price (P)*
	Procurement administration cost / order cost	*C*	$C = \frac{Adm}{R}\ x\ n$
	Unloading and maintaining cost	*M*	Rp. 6,840.00 per ton
	Inspection cost	*A*	Rp. 1,364.00 per ton

Variable cost (VC) consists of calculation of steam production cost obtained from the simulation of price and quality of coal. While the delivery time contributes to the inventory cost reduction calculation. Labor costs are influenced by the procurement frequency performed. After calculation on all procurement strategy, hence obtained by total benefit and total cost so that obtained result of calculation as follows:

Table 5. Benefit, cost and cost savings value of each procurement strategy.

Strategy	Total benefit (Rp/ton)	Total cost (Rp/ton)	Cost savings (Rp/ton)
ST-3	1,399,716.24	710,833.02	-
ST-4	1,460,133.86	707,812.07	3,020.95
ST-6	2,581,815.62	708,216.89	2,616.13
LT-12	2,846,999.98	688,639.92	22,193.10
LT-24	2,899,209.51	686,356.38	24,476.64
LT-36	2,927,787.61	686,070.94	24,762.08
MT-12/3	2,111,524.24	702,151.55	8,681.47
MT-12/4	2,315,733.49	701,485.50	9,347.52

Strategy	Total benefit (Rp/ton)	Total cost (Rp/ton)	Cost savings (Rp/ton)
MT-12/6	2,675,486.36	694,468.34	16,364.68
MT-24/3	2,002,375.54	699,321.43	11,511.59
MT-24/4	2,467,259.64	697,775.66	13,057.36
MT-24/6	2,757,071.67	692,375.80	18,457.22
MT-36/3	2,095,348.52	701,201.51	9,631.51
MT-36/4	2,170,258.59	695,849.06	14,983.96
MT-36/6	2,727,451.87	692,067.18	18,765.84

With an average discount rate of 6.79%, to calculate the Net Present Value (NPV), first we have to calculate the Present Value (PV) of each benefit and cost as follows:

Short – term Strategy 3 month (ST-3)

$$PV(B) = \sum_{t=0.25}^{n} \frac{B_{0.25}}{(1+s)^{0.25}}$$

$$PV(B) = \left(\frac{S}{(1+s)^{0.25}}\right) + \left(\frac{Q}{(1+s)^{0.25}}\right) + \left(\frac{I}{(1+s)^{0.25}}\right) + \left(\frac{W}{(1+s)^{0.25}}\right)$$

$$PV(B) = \left(\frac{1{,}376{,}929.52}{(1+6.79\%)^{0.25}}\right) + \left(\frac{0}{(1+6.79\%)^{0.25}}\right) + \left(\frac{0}{(1+6.79\%)^{0.25}}\right) + \left(\frac{0}{(1+6.79\%)^{0.25}}\right)$$
$$PV(B) = \text{Rp. } 1{,}376{,}929.52 + \text{Rp. } 0 + \text{Rp. } 0 + \text{Rp. } 0$$
$$PV(B) = \text{Rp. } 1{,}376{,}929.52 \text{ / ton}$$

$$PV(C) = \sum_{t=0.25}^{n} \frac{C_{0.25}}{(1+s)^{0.25}}$$
$$PV(C) = \left(\frac{P}{(1+s)^{0.25}}\right) + \left(\frac{C}{(1+s)^{0.25}}\right) + \left(\frac{M}{(1+s)^{0.25}}\right) + \left(\frac{A}{(1+s)^{0.25}}\right)$$
$$PV(C) = \left(\frac{702{,}533.76}{(1+6.79\%)^{0.25}}\right) + \left(\frac{95.27}{(1+6.79\%)^{0.25}}\right) + \left(\frac{6{,}840.00}{(1+6.79\%)^{0.25}}\right) + \left(\frac{1{,}364.00}{(1+6.79\%)^{0.25}}\right)$$
$$PV(C) = \text{Rp. } 691{,}096.84 + \text{Rp. } 93.72 + \text{Rp. } 6{,}728.65 + \text{Rp. } 1{,}341.79$$
$$PV(C) = \text{Rp. } 699{,}261.00 \text{ / ton}$$

$$NPV = PV(B) - PV(C)$$
$$NPV = \text{Rp. } 1{,}376{,}929.52 - \text{Rp. } 699{,}261.00$$
$$NPV = \text{Rp. } 677{,}668.52 \text{ / ton}$$

In the same way we calculate the Present Value (PV) benefits and cost for other procurement strategies so that the following results were obtained:

Table 6. Present value (PV) of benefits and cost & NPV for each procurement strategy.

Strategy	PV (*B*) (Rp/ton)	PV (*C*) (Rp/ton)	NPV (Rp/ton)
ST-3	1,376,929.52	699,261.00	677,668.52
ST-4	1,428,526.46	692,490.12	736,036.34
ST-6	2,498,438.39	685,345.72	1,813,092.68
LT-12	2,666,086.94	644,880.20	2,021,206.74
LT-24	2,542,455.07	601,898.64	1,940,556.43
LT-36	2,404,363.34	563,416.49	1,840,946.85
MT-12/3	1,945,156.84	646,828.90	1,298,327.94
MT-12/4	2,121,636.77	642,689.43	1,478,947.34

Strategy	PV (*B*) (Rp/ton)	PV (*C*) (Rp/ton)	NPV (Rp/ton)
MT-12/6	2,424,560.39	629,336.20	1,795,224.19
MT-24/3	1,727,267.53	603,201.95	1,124,107.50
MT-24/4	2,116,727.79	598,604.81	1,518,154.38
MT-24/6	2,339,665.18	587,528.21	1,752,157.73
MT-36/3	1,692,499.71	566,312.70	1,126,265.58
MT-36/4	1,743,509.08	558,960.80	1,184,606.94
MT-36/6	2,167,394.16	549,910.08	1,617,522.96

4.4 Risk Analysis

At the risk identification stage, we combine aspects of supply chain risk developed by the Supply Chain Risk Leadership Council (SCRLC, 2011) consisting of three categories: external - end to end risk, supplier risk, & internal enterprise risk, each consisting of 8, 5 and 11 consecutive risk factors, and the supply risk aspect developed by Tang & Tomlin (2008) in Zsidisin & Ritchie (2008) consists of 3 (three) risks namely supply cost risk, supply commitment risk, supply continuity risk. The four aspects of risk are set forth in the questionnaire using Likert's scale (1 to 5), to measure the perceptions of risk of respondents to each risk.

Based on the assessment of risk, processing is done by calculating the Severity Index (SI) for each risk in each procurement strategy, such as the following calculation example:

Probability / likelihood.

<u>3 month short term procurement strategy (ST-3), for risk variable X1.</u>

$$Severity\ Index = \left(\frac{\sum_{i=0}^{4} a_i x_i}{4\sum_{i=0}^{4} xi}\right)(100\%)$$
$$= \left(\frac{(0x1)+(1x3)+(2x0)+(3X1)+(4x0)}{4\text{x}(1+3+0+1+0)}\right)(100\%)$$
$$= 30$$

Referring to the rating scale, the value of Severity Index (SI) 30 is on a scale of 2.

The calculation of severity index (SI) is performed for all risk variables in each procurement strategy and calculated the average severity index (SI) value for severity / consequences, so as to obtain the calculation results as in the following table:

Table 7. Probability, Severity and Risk Value of each procurement strategy.

Procurement Strategy	Probability	Severity	R
ST-3	1.56	1.74	2.71
ST-4	1.63	1.78	2.90
ST-6	1.48	1.78	2.63
LT-12	1.22	1.59	1.95
LT-24	1.30	1.78	2.30
LT-36	1.41	1.85	2.61
MT-12/3	1.11	1.19	1.32
MT-12/4	1.00	1.41	1.41

Procurement Strategy	Probability	Severity	R
MT-12/6	1.19	1.48	1.76
MT-24/3	1.00	1.15	1.15
MT-24/4	1.04	1.41	1.46
MT-24/6	1.04	1.44	1.50
MT-36/3	1.00	1.22	1.22
MT-36/4	1.04	1.30	1.34
MT-36/6	1.04	1.44	1.50

5. Results

5.1 Cost-Benefit Analysis

The steam price in the Cost-Benefit Analysis (CBA) is calculated based on the costs required to produce steam as follows:

1. Variable cost, where the main component is the steam production cost which consists of three costs, namely the cost of coal consumption, the limestone consumption cost, and the ash processing cost, plus the other costs.
2. Fixed cost in this study is the cost incurred in the production process that is independent of the amount of steam produced. The amount of fixed cost in this research is Rp. 80,523.21 per ton.

The calorific value parameter of the 3-month short term procurement strategy (ST-3) is the lowest of 5342.24 kcal / kg with the highest coal price of Rp. 702,533.76 per ton, compared to other strategies, so the cost of coal consumption of this strategy became the highest. In contrast to the 36 month long procurement strategy (LT-36) has the highest value of calorific value 5419.10 kcal / kg with the lowest coal price of Rp. 677,842.78 per ton, so the cost of coal consumption became the lowest. With the same fixed cost, the total steam price per ton of 3-month short-term procurement strategy (ST-3) and 36 month long procurement strategy (LT-36) is also the highest and lowest sequence of Rp. 233,475.21 and Rp. 225,753.53 per ton of steam.

On the production side, 1 (one) unit of coal weight (ton) fed into a coal boiler will produce different steam depending on the calorific value. In accordance with the calculation results, the highest steam production per ton of coal consumption is in the 36 month long procurement strategy (LT-36) with production of 6.17 ton of steam per ton of coal where in this strategy the value of calorific value of coal is the highest i.e., 5419.10 kcal / kg. The highest steam price per ton of coal is in the 6 month short term procurement strategy (ST-6) at a price of Rp. 1,411,892.75 per ton of coal. The steam price per ton of coal may not be linear in accordance with the amount of steam production per ton of coal consumption due to the price of steam per ton of coal representing the multiplication of steam price per ton (S) and steam production per ton of coal consumption, where the price of steam per ton of procurement strategy length 36 months (LT-36) is lower than the short-term procurement strategy of 6 months (ST-6) by Rp. 3,964.72 per ton or 1.73%.

The calorific value influences the productivity improvement of each procurement strategy. Based on the above data, the 36 month long-term procurement strategy (LT-36) has the highest productivity increase with a value of Rp. 1,554,040.26 per ton. This could mean a long-term procurement strategy of 36 months (LT-36) is better than the existing strategy in terms of steam price per ton of coal produced.

The highest inventory cost is in the 3 month short-term procurement strategy (ST-3). This is because the cost per unit of goods (purchase cost) which in this case the price of coal simulation results in this strategy is the highest i.e., Rp. 702,533.76 per ton. The highest reduction of inventory costs lies in the 24-month long-term procurement strategy (LT-24), as this strategy has the lowest inventory cost value. Based on the data in the table above, it can be said that the 24 months long term procurement strategy (LT-24) is better than the existing strategy in terms of inventory cost and inventory cost reduction. The component cost per unit of goods (purchase cost) effect on inventory cost reduction, where the lower cost per unit of goods (purchase cost) then the total cost of inventory will be lower. This is because the average component cost per unit of goods (purchase cost) contributes 90.84% of total inventory costs.

The reduction of labor costs is directly proportional to the frequency of ordering and inversely proportional to the total consumption of coal. This means that the higher the ordering frequency the higher the labor cost so that the reduction of labor costs will be higher and vice versa. However, the higher total coal consumption per year will lower labor costs so that the reduction of costs will also be lower.

Based on the calculation, investment cost / purchase of coal affect the cost of coal consumption per year, where the lower the cost of investment / purchase of coal then the cost of coal consumption per year will also be lower. The cost of procurement administration is influenced by the frequency of ordering and total consumption of coal per year, where the higher the frequency of ordering the higher the cost.

From the calculation of Net Present Value (NPV), we obtained that the highest value is in the long-term procurement strategy of 12 months (LT-12) of Rp. 2,021,206.74. This means that if only considering benefits and costs, the 12-month long-term procurement strategy (LT-12) is the best strategy to apply in this case study, in accordance with predetermined limits and assumptions.

5.2 Risk Analysis

Based on the results of data processing and calculation, the highest risk factor (R) in the procurement process is Operational Risk on the internal risk aspect of the risk level 4 and is at medium risk level, while other risk factors are at low risk level. Overall, the highest level of probability / likelihood risk was on a 4-month short-term procurement strategy (ST-4) of 1.63 and the impact of risk (severity / consequences) was on long-term procurement strategy 36 month (LT-36). Based on the value of the risk level, the mixed 24 and 3-month mix strategy becomes the strategy with the lowest risk value with value 1.15 and is at low risk level. This means that if we only consider the coal supply procurement risk analysis, a mixed 24 and 3 month mix strategy is the best strategy to apply in this case, in accordance with predetermined limits and assumptions.

5.3 Aggregation of CBA and Risk Analysis scores

This study aims to determine the best combination of procurement strategies by considering the cost and benefit analysis aspects as well as the procurement supply risk analysis. For this purpose, the aggregation calculation of the values resulting from the two analyzes is obtained so that the best procurement strategy is a 24 month long and 6 month short-term mixed-term procurement strategy (MT-24/6) with the final value of 1.60 which is the highest value compared to other procurement strategies. The decision is possible because the strategy has a value of Net Present Value (NPV), which tends to be high, which is Rp. 1,752,136.96 and the low risk level value that is 1.50.

6. Conclusion

In this paper we evaluate three strategies with respect to procurement contract periods for coal. Evaluation was based on both financial performance and risks. The Monte Carlo simulation was used to obtain the performance of each alternative strategy and the Cost-Benefit analysis was applied to make comparisons. The procurement lead time and the coal quality was taken into account in the model. The results suggest that 12-month contract period provides the lowest in terms of the total costs, but not necessarily the best in terms of the risks. The mixed strategy combining the portion of supply volume with 24-month contract and the rest is covered by a shorter term (6-month contract) is proven the best from risk point of view. This mixed strategy also outperformed both other strategies when we evaluate the alternative strategies based on both financial aspect as well as risks. The results are sensible. As the uncertainty arises in the price of commodities, putting long-term contract could be harmful for both sides. On the other side, too short contract period is costly since the company has to process too many procurement contracts. The exact combination, however, may vary from case to case. A more comprehensive experiments may be needed to obtain a recommended range under wider situations.

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