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Business Intelligence for Decision Support System for Replenishment Policy in Mining Industry

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ABSTRACT

The mining industry has unique characteristics in the sense that usually, the plant is located in a remote area while the headquarters are located in an urban area. These conditions pose challenges for the industry related to coordination within companies. This coordination is very important, especially in relation to the decision-making that must be carried out by the company. One of the important managerial decisions is related to the replenishment policy. To make replenishment decisions, companies need past data, such as biodiesel consumption rate, and current data, such as current stock and storage capacity, where the source of those data is in the plant. Often, decisions must be taken quickly because they have impacts on the continuousness of production operations at the plant. However, the remote location and shipping routes across rivers have created new challenges in the flow of goods and services supply because the shipment depends on the tides of the river. This research proposes a business intelligence system that collects, sorts, and visualizes data, then analyzes the replenishment decision to support decision-making in the mining industry. The system uses Microsoft Power BI software which is integrated with the company's ERP system. To illustrate the applicability of the proposed system, it is applied to a coal mining company, especially in relation to the replenishment policy of biofuel. The result of this study indicates that the proposed system can work. In addition, it can reduce decision-making time by 220.65%.

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1. INTRODUCTION

The importance of data in business decisions drives the growth of business intelligence practices (Kurniawan et al., 2021). Currently, business intelligence has been applied in many areas. For example, Akbar et al. (2017) implemented business intelligence at a university to find out which majors are most in demand in the process of admitting new students. Meanwhile, Afikah et al. (2022) implemented business intelligence to analyze data on COVID-19 infection cases by creating dashboards on the number of confirmed cases, deaths, and recoveries for further decision-making. Business intelligence has been used in various businesses according to their needs, such as predicting the price of CPO and gold using the Simple Evolving Connectionist System model (Al-Khowarizmi et al., 2020; Purba et al., 2021), predicting economic growth with the Multilayer Perceptron Model and Gene Expression Programming (Ahmadi et al., 2019), and the use of site reliability engineering in implementing application monitoring solutions in data-based projects (Fedushko et al., 2020).

Business analytics techniques play an important role in supporting the development of business intelligence (BI). According to Evan (2019), there are three types of business analytics techniques: 1) descriptive techniques, 2) predictive techniques, and 3) prescriptive techniques. Descriptive techniques discuss data visualization, where the result of data analysis is presented in graphical or tabular form. Predictive techniques explain several techniques to make predictions, such as multiple linear regression. At the same time, prescriptive techniques focus on what-if analysis using several tools, such as simulation. Prescriptive analytics provides direct support for decision-making, hence, fills the gaps between data and decision (Frazzetto et al., 2019). Prescriptive analysis has been used quite widely in logistics, for example, for planning multi-item newsvendor inventory in the retail industry (Punia et al., 2020), inventory replenishment of medical products (Galli et al., 2021), and vehicle routing planning (Soeffker et al., 2022).

To the best of the author's knowledge, there is little attention given to the research on combining prescriptive models, especially those for determining replenishment policy in the mining industry, with BI. This study presents the work to develop a BI system based on a model for determining replenishment policy in the mining industry. To illustrate the applicability of the proposed BI system, a real-life case study is used. Raw data is taken from the ERP system, which will then be sorted so that it is ready to be analyzed with the BI system. A real case study is taken from a coal mining company that has problems determining the replenishment policy for fuel. The problem is characterized by a situation in which the plant and headquarters are far from each other. Therefore, it is necessary for this company to make an accurate decision without delay. According to Bokde et al. (2020), mining is one of the sectors with a large amount of biodiesel fuel consumption. The mining industry uses biodiesel fuel in power plants, heavy vehicles, light vehicles, blasting activities, machinery, and water pumps.

After this Introduction section, the organization of this paper is as follows: Section 2 presents some related literature. Section 3 discusses the existing system related to the replenishment policy applied in the company, followed by the proposed BI system based on the model for replenishment policy. An explanation of the case study to illustrate the applicability of the proposed system is discussed in Section 4. The result from the proposed system is then compared with the result from the existing system. Finally, section 5 concludes the research findings.

2. LITERATURE REVIEW

Business intelligence ensures the accuracy of decisions and the smooth running of business processes. A wide variety of assisting software helps this increase (Fatima & Linnes, 2019). Business intelligence applies concepts and combines architectural segments, support tools, database processing, analysis tools, and methodologies simultaneously, which can produce output in the form of processed data that has been visualized in the form of reports and dashboards (Pavkov et al., 2016). The results of this analysis and visualization support companies in making various decisions regarding operational efficiency and business development.

Frequently, decision-making is based on the most accurate estimates available in the respective field. A large number of fields, such as energy, economics, infrastructure, health, agriculture, defense, education, technology, geoscience, climate, and structural engineering, use and exploit the benefits of time series forecasting (Bokde et al., 2020). Forecasting is a field of science that is used as a tool to predict something based on existing data and is processed in a certain way (Maricar, 2019). Forecasting is a general data science that assists organizations in capacity planning, goal setting, and anomaly detection. Producing accurate and high-quality forecasts, particularly when there are fluctuations in the time series data, is a challenge in forecasting (Taylor & Letham, 2018). Therefore, researchers and business managers have developed new tools to increase forecasting accuracy. For example, Afandi et al. (2022) used the Apriori algorithm and the moving average model to predict stocks. Further, considering the uncertainty of demand, a supply chain can use big data in inventory decisions (Bertsimas et al., 2016). There are many applications in the form of machine learning, which uses large-scale, web-based data to generate predictions of true quantities that might be used in operations management applications (Da et al., 2011; Goel et al., 2010; Gruhl et al., 2004; Gruhl et al., 2005; and Kallus, 2014).

There are several technologies that support business intelligence (BI); one of them is Microsoft Power BI. Microsoft Power BI is a user-friendly software for data analysis in the domain of business intelligence (Khalwadekar & Gogate, 2022). People can use it to combine, analyze, visualize, and share data (Becker & Gould, 2019). Several studies reported the application of Microsoft Power BI and its advantages. It has been applied to the crude palm oil industry to forecast CPO prices using a time series algorithm (Albara et al., 2021), measure logistics performance in transportation companies (da Silva et al., 2020), make production floor dashboards in the chemical industry (Salvadorinho et al., 2020), and use interactive visualization in education (Bhargava et al., 2018).

3. METHODS

This section describes the research method, starting with the identification of current biodiesel fuel ordering systems. The second part presents the proposed business intelligence system. The stages, including the calculation of the replenishment, are explained.

3.1. Existing system related to the replenishment policy applied in the company

The headquarters and the plant are located in different areas, as shown in Figure 1. The headquarters are located in location A, while the plant is located in location C. Recently, to calculate the quantity order, the company used data retrieved from their ERP software, and then they did calculations to determine the quantity order. The result of this calculation is used as input for generating a

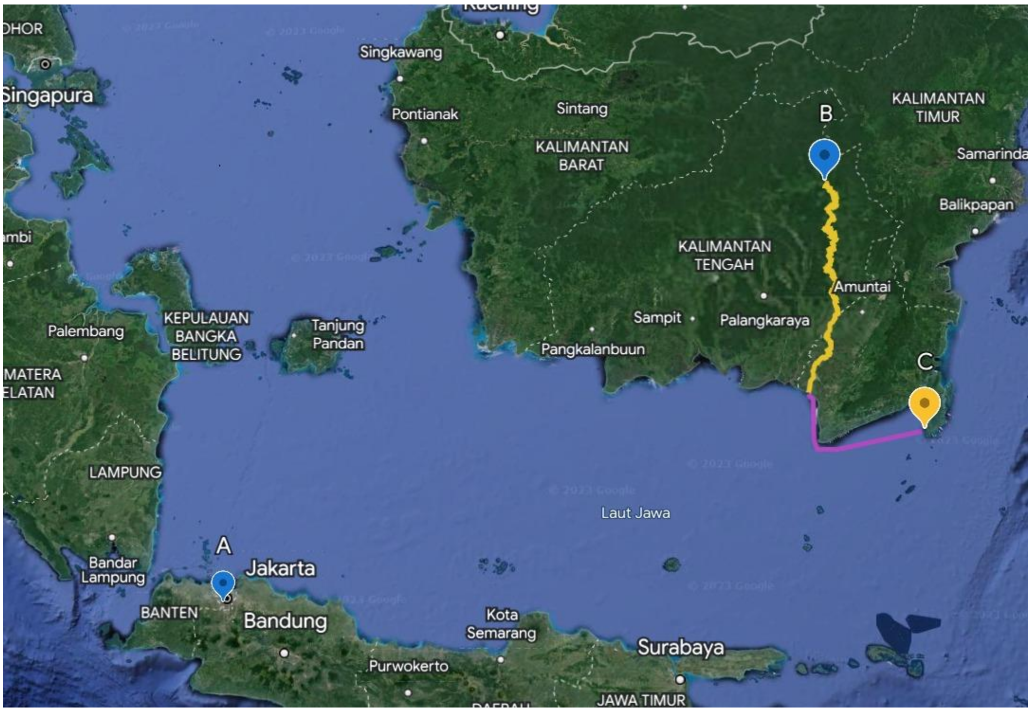

Figure 1. The location of headquarter and the plant

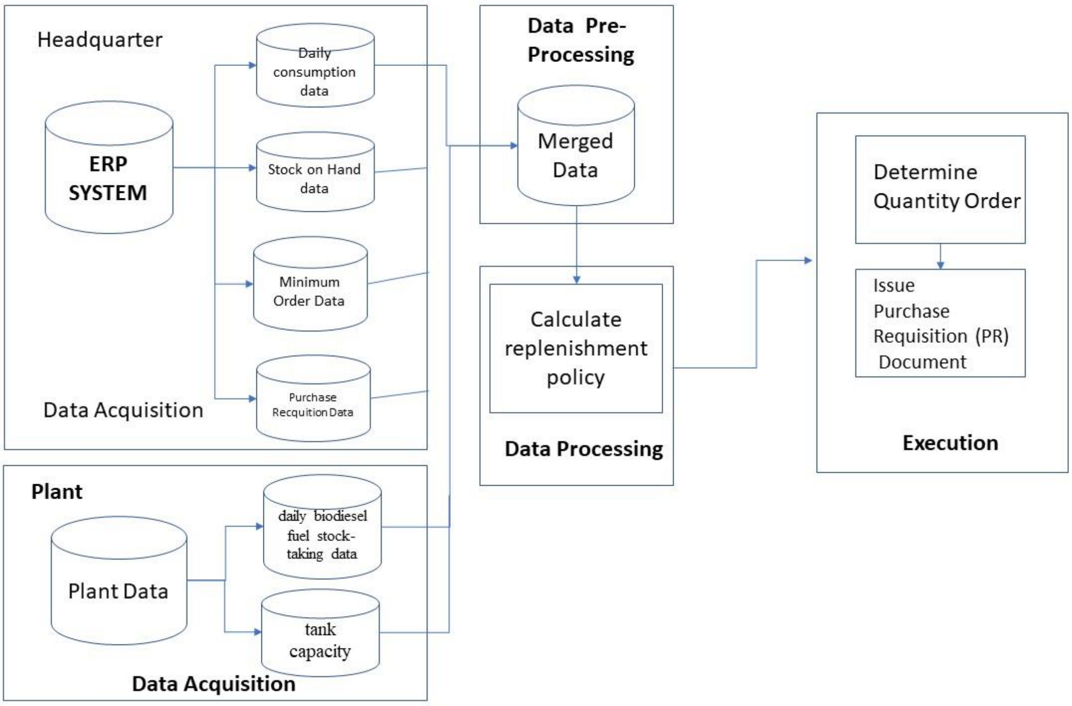

Figure 2. The stages of the current ordering method for biodiesel fuel and the tools used

purchase requisition (PR). The flow of this activity is depicted in Figure 2.

Figure 2 shows the stages of the current ordering method for biodiesel fuel, where the processes of compiling databases, data processing, and determining ordering decisions are carried out with the help of Microsoft Excel software. The evaluation of the current method found that Microsoft Excel struggles to handle a large amount of data and often gives the "Not Responding" error with a large quantity of data. In addition, due to the different locations of the headquarters, it takes a longer time to coordinate among members within the company.

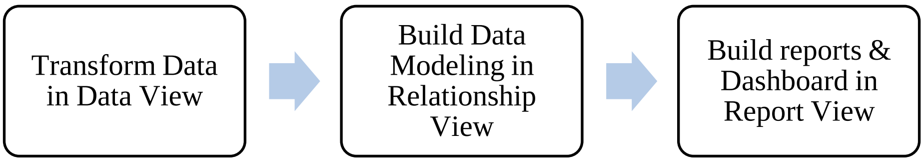

Figure 3. Microsoft Power BI Workflow

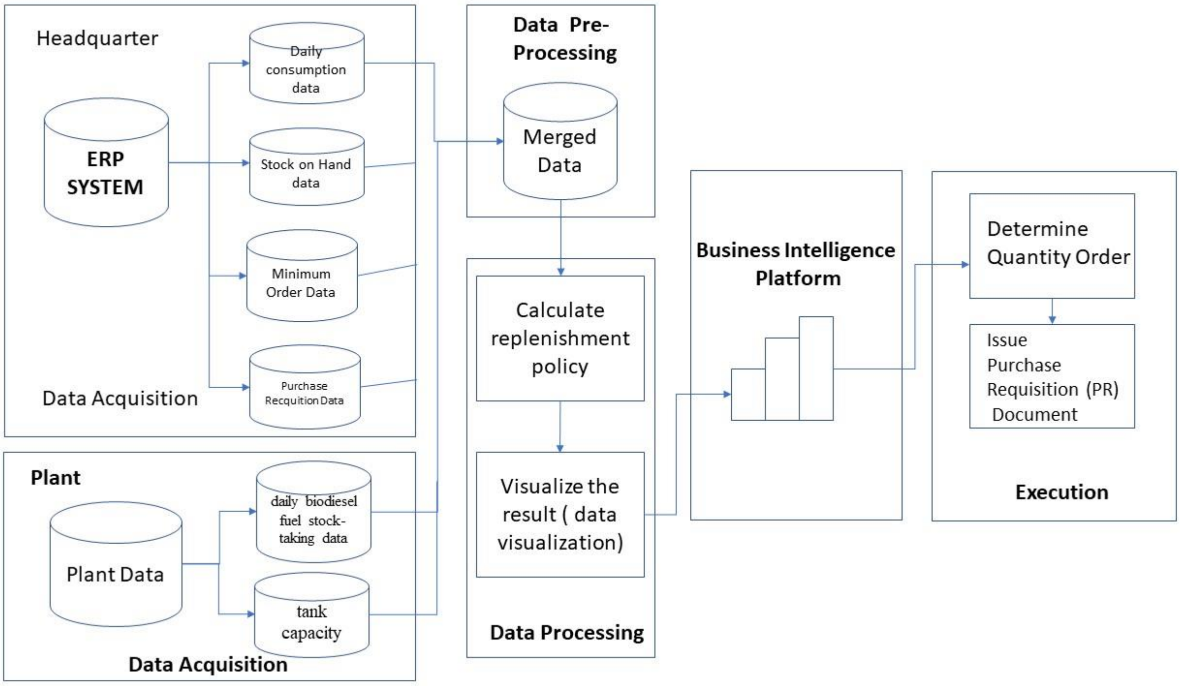

Figure 4. A framework of the proposed BI system

3.2. Proposed Business Intelligence System for Decision Support System for Replenishment Policy in Mining Industry

In this section, a proposed business intelligence (BI) system is developed. The proposed BI system can be seen in Figure 3. In the proposed system, a new ordering method is implemented by utilizing Microsoft Power BI software to handle large amounts of data with the Power Pivot engine model. More importantly, it does not restrict itself to any specific versions of Microsoft Excel or Office 365 and manages data with a more attractive visualization.

To make a report in Microsoft Power BI, steps are needed in accordance with Figure 3 to present data and provide thorough and precise analysis. The first is by transforming the data. The second step is to build data modeling in Relationship View. Data is aggregated by relationships and filtered in reports only to show data that is relevant for analysis, as also shown in Figure 4. After we have our data model, all the measures, and all the formulas, we can visualize our data in the third step.

Based on Figure 4, it can be seen that the proposed framework consists of five stages, as follows:

1. The first stage is the data acquisition stage. At this stage in the proposed framework, it is suggested that companies retrieve data from their ERP software. The data collected includes 1) daily consumption data (the usage of material); 2) stock-on-hand data; 3) minimum order data; and 4) purchase requisition data. In addition to taking data from the ERP software, data is also taken from the plant, namely fuel consumption data and tank capacity data.
2. The second stage is the pre-processing stage. At this stage, the data that has been obtained in the first stage is combined. This merger facilitates the next step, as it is easier and faster to work with fewer data files than more. Compiling the Microsoft Excel dataset using Microsoft Power BI software by adjusting the relationships among the data. In Microsoft Power BI, primary keys and foreign keys are used to create data relationships.
3. The third stage is the calculation of the replenishment policy. The existing policy is used to anticipate uncertainty. The stock replenishment policy follows the maximum tank capacity limit at the site location, which is 8,441,000 liters. The stages of carrying out a replenishment policy are carried out as follows:
   a. Demand Forecast (D) using Exponential Moving Average (Holt et al., 1955) (1.1)

$$D = (\text{Last Usage} - \text{Average Quantity}) \times \frac{\alpha}{n+1} + \text{Average Quantity} \quad (1)$$

   where:

α = constant of exponential moving average.
n = periods (month).
Last usage = last usage quantity (quantity from last month).
Average Quantity = average quantity per month (one-year data).

b. Safety Stock (Heizer and Render, 2015)

$$SS = Norm.S.Inv\ (SL) \text{ x } \sqrt{(LT \text{ x } Stdev.P\ Dmd^2) + (D \text{ x } Stdev.P\ LT^2)} \quad (2)$$

where:
SS = safety stock.
LT = service level; the expected probability of not hitting a stock-out during the next replenishment cycle.
Norm.S.Inv = normal distribution with a mean of 0 and a standard deviation of 1.
Stdev.P Dmd = variability of demand in a certain period.
Stdev.P LT = variability of lead time in a certain period.

c. Minimum and Maximum Stock

$$\text{Minimum Stock} = (D \text{ x } LT) + SS \quad (3)$$

Minimum Stock is the minimum quantity of material that must be kept at all times. Maximum Stock is the maximum quantity of materials specified based on the tank capacity. The company always fills the tank full of anticipating the conditions where fuel cannot be delivered. River conditions cannot be crossed by the ship (Self Propeller Oil Barge /SPOB) if the water level is below 2.4 meters or more than 6.8 meters. If the water level is below 2.4 meters, the SPOB cannot make a delivery, while if the level is 6.8 meters, the water level is too high, which causes the SPOB to crash into the bridge across the river.

d. Determination of the quantity to be ordered (Nomination Order). The fourth step is determining the quantity of biodiesel fuel ordered.

$$\text{Nomination Order} = \text{Maximum Stock} - (SOH + \text{On Order}) - \text{Demand Forecast} \quad (4)$$

Nomination Order is a purchase plan that requires General Manager's approval.
SOH = stock-on-hand.
On Order = amount of fuel that will arrive from the previous purchase order.

4. The fourth stage is to create a BI for data visualization with Microsoft Power BI. Using this BI, information regarding replenishment policies is displayed so that management can monitor stock.
5. Creating Purchase Orders. The fifth step is to make a purchase order to the supplier from the approved nomination order. Based on the result of the previous step using Microsoft Power BI, PR generation can be carried out automatically.

Power BI is very helpful in analyzing data by collecting several reports and several datasets into one dashboard.

4. RESULTS AND DISCUSSION

4.1. An explanation of the case study to illustrate the applicability of the proposed framework

In this section, a real-life case study is used to illustrate the applicability of the proposed system. The company is currently using a system described in Section 2 where there are weaknesses, especially related to coordination between departments, given that the headquarters and plant locations are far apart. In addition, the length of time needed to be able to decide on the quantity order is long for data processing and validation. At the implementation stage, the steps start with:

1. Perform data retrieval for both data owned by the company's ERP software and data from the plan, as explained in the section.
2. Doing pre-processing by compiling the data, where at this stage, it is ensured that for the tables to be joined, the primary key from one table becomes a foreign key in another table. The results can be seen in Figure 5.
3. Perform calculations to determine replenishment policies, which are related to determining orders, using formulas (1), (2), (3), and (4). Calculations were performed with the help of Microsoft Excel, as can be seen in Table 1. The fuel that can be ordered is located in the Empty Space column, which is the tank capacity subtracted by the estimated fuel stock at the end of the month. Also the stock replenishment policy also follows the maximum tank capacity limit at the site location, which is a maximum capacity of 8,441,000 liters.
4. Perform data visualization to determine the fuel to be ordered, as shown in Figure 6.

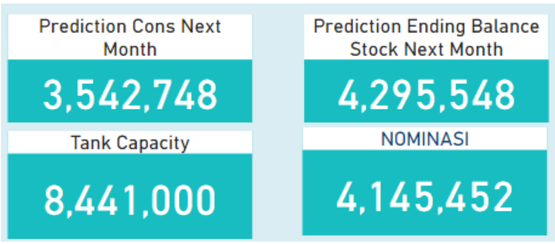

Figure 6. Making visualizations in Microsoft Power BI

In this study, the data of 2022 is used to compare the data processing using the existing system (Microsoft Excel) and using proposed system (Microsoft Power BI). In this visualization, Microsoft Power BI can display the predicted results of consumption and stock at the end of October after the data has been calculated and analyzed in step 3.

4.2 Data processing using an existing system (Microsoft Excel)

Table 2 shows the biodiesel fuel consumption plan the Finance Department approved for 2022. In Table 3, the number shows the actual consumption that has been

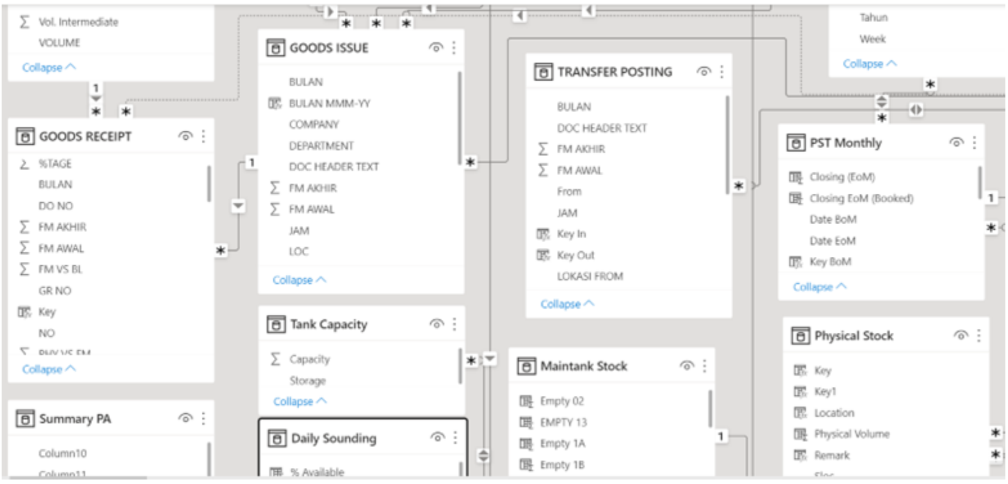

Figure 5. An example of the steps in merging data tables

Table 1. Calculation of the order quantity

Month	Sisa Hari	Eta Konsumsi	EOMM	Capacity	Eta Stock EOM	Stock AMC EOM	Forecast	Stock Next Month	Empty Space	Stock Onsite
Sep-22	7	653.628	30 September 202	8.441.000	4.830.834	4.830.834	2.895.188	1.935.645	6.505.355	5.352.401
Sep-22	6	560.253	30 September 202	8.441.000	4.845.129	4.845.129	2.895.188	1.949.941	6.491.059	5.273.321
Sep-22	5	466.877	30 September 202	8.441.000	4.764.649	4.764.649	2.895.188	1.869.460	6.571.540	5.099.465
Sep-22	4	373.502	30 September 202	8.441.000	5.895.011	5.895.011	2.895.188	2.999.823	5.441.177	6.136.452
Sep-22	3	280.126	30 September 202	8.441.000	6.788.656	6.788.656	2.895.188	3.893.467	4.547.533	5.971.687
Sep-22	2	186.751	30 September 202	8.441.000	6.801.250	6.801.250	2.895.188	3.906.062	4.534.938	5.890.906
Sep-22	1	93.375	30 September 202	8.441.000	7.840.177	7.840.177	2.895.188	4.944.988	3.496.012	6.836.457
Sep-22	0	0	30 September 202	8.441.000	7.932.820	7.932.820	2.895.188	5.037.632	3.403.368	6.835.725
Sep-22	30	2.801.265	31 October 2022	8.441.000	5.082.969	5.082.969	2.895.188	2.187.781	6.253.219	6.695.214
Oct-22	29	2.707.889	31 October 2022	8.441.000	5.057.255	5.057.255	2.410.401	2.646.853	5.794.147	6.576.124

distributed, which is from October 2021 to September 2022 in this case study.

Table 4 shows the calculation of the nomination order for October. First, there is stock on hand (SOH), current fuel on order, and average usage (AVG) data. The arrival of biodiesel fuel from the Purchase Order release takes 17 days. So, the LT is 17/30 = 0.67 months. According to Equation (3), the minimum stock with a service level of 84% is 2,505,556 liters. Meanwhile, we use the maximum tank capacity at the site of 8,441,000 liters for the maximum stock.

In calculating the consumption or demand forecast for October 2022, the α is 1.75 based on the company's Standard Operating Procedure (SOP). Based on the calculation, a forecast demand of 3,542,748 liters of biodiesel fuel was performed. Then, using the equation [4], the number of nominated (planned) biodiesel fuel that will be proposed is 4,145,452 liters to fulfill the fuel tank.

Table 2. Consumption plan of biodiesel fuel in 2022

Month	Consumption plan
January	2,286,648
February	2,239,030
March	2,697,897
April	2,964,503
May	3,089,913
June	2,997,126
July	3,174,685
August	3,499,686
September	3,452,656
October	2,689,549
November	2,239,196
December	2,737,164

Table 3. Actual biodiesel fuel consumption to date

Month	Consumption data
October (2021)	2,425,943
November (2021)	2,268,096
December (2021)	2,364,195
January (2022)	2,280,002
February (2022)	2,141,671
March (2022)	2,739,170
April (2022)	2,969,171
May (2022)	3,085,245
June (2022)	2,997,126
July (2022)	3,158,449
August (2022)	3,499,686
September (2022)	3,445,826

4.3. Data processing using the proposed system (Microsoft Power BI)

Using Microsoft Power BI, data can be managed quickly with a more attractive visualization display. For example, in Figure 7, the tank capacity can be found quickly. The remaining tank capacity is shown with numbers on a green background, while the amount of fuel in the tank is shown in percentage and blue background. Figure 8 shows stock conditions at the end of September

Table 4. Calculation of biodiesel fuel order

SOH	On Order	*AVG* (Qty)	*SS*	*LT*	Min (Qty)	Max (Qty)	Demand Forecast	Nomination (planned)
6,741,201	1,097,095	2,781,215	1	0.67	2,505,556	8,441,000	3,542,748	4,145,452

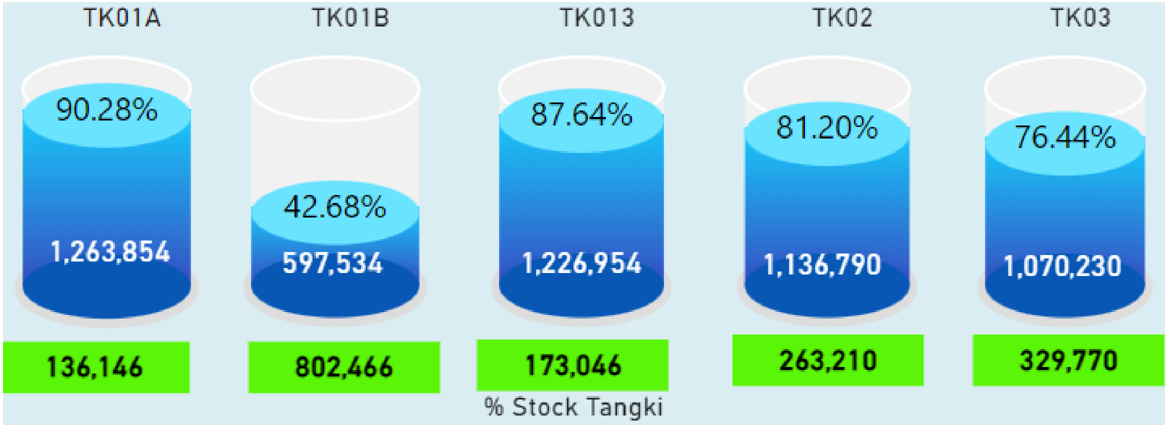

Figure 7. Visualization of tank capacity, including the remaining capacity

Figure 8. Dashboard for nomination calculation

2022. The information highlighted on this dashboard is the total capacity tank, the forecast for biodiesel fuel consumption, the forecast stock on hand end of October, and the amount of biodiesel fuel that must be ordered is 3,497,892. Other information that is displayed is stock on hand at the site on the current date and fuel on orders that are still in progress (in this case, at SPOB). In addition, we display the details of the data we want on the dashboard.

4.4. Evaluation of data management time

Table 5 shows a comparison of data processing time using Microsoft Excel and Microsoft Power BI. It presents the time required to perform all the activities. The result shows a time reduction after using Microsoft Power BI, which means increased efficiency.

The above results show that Microsoft Power BI can reduce processing time and help inventory workers make forecasts and replenishment decisions, similar to Kongprasert et al. (2021). In this study, regarding the biodiesel fuel ordering model using Microsoft Power BI, it was found that the processing time decreased by 220.65%, from 3.42 hours to 1.55 hours. This result supports the findings of Albara et al. (2021) and Kongprasert et al. (2021). Visualization using Microsoft Power BI also makes easier decisions on business policies in the CPO industry (Albara et al., 2021). The data is presented faster because it only uses one interface without combining each Microsoft Excel formula.

Table 5. Evaluation of efficiency results

No		Activity	Minute	Hour	Minute	Hour
			Microsoft Excel		Microsoft Power BI	
1		Run Month Movement History	35	0.58	10	0.17
	a	Download SAP MB51	5	0.08	5	0.08
	b	Data Processing MB51 (Month Movement)	30	0.5	5	0.08
2		Update User Forecast	10	0.17	5	0.08
3		Compare and Check the History & Forecast	30	0.5	5	0.08
4		Calculate Min Max	60	0.92	23	0.38
	a	Download SAP ME5A	5	0.08	5	0.08
	b	Download SAP ME2N	5	0.08	5	0.08
	c	Download SAP MM60	5	0.08	5	0.08
	d	Data Processing Lead Time	30	0.5	3	0.05
	e	Review Min Max	15	0.17	5	0.08
5		Nomination Calculate	40	0.75	25	0.42
	a	Download SAP MB52	5	0.17	5	0.08
	b	Check Stock On Hand	10	0.17	5	0.08
	c	Review MRP SAP	15	0.25	5	0.08
	d	Adjustment Quantity Order	10	0.17	10	0.17
6		Create Purchase Requisition	25	0.42	25	0.42
	a	Filling Nomination order Quantity	5	0.08	5	0.08
	b	Attach supporting data/references	10	0.17	10	0.17
	c	Input Purchase Requisition	5	0.08	5	0.08
	d	Check and post Purchase Requisition	5	0.08	5	0.08
		Total Lead Time Process	205	3.42	93	1.55

5. CONCLUSION

In this mining industry case study, a business intelligence system is proposed by combining the existing ERP system that provides the data and Microsoft Power BI that visualize them as a decision-making dashboard. Prescriptive analytics is built to forecast the demand and calculate the replenishment decision. In a business intelligence system, such as Microsoft Power BI, we can connect many different data types. We use data sources in the form of Microsoft Excel files. Microsoft Power BI can display various kinds of data visualizations with attractive appearances. It helps inventory workers make forecasts and make decisions faster, even when they are in remote locations, far from the head office. However, the Microsoft Power BI used in this research is a free version, so it does not support sharing datasets, reports, and dashboards. To overcome this, mapping source datasets is done manually on each computer. Also, datasets stored in shared capacities in the Power BI service have a 1-GB size limit. Further study may overcome this limitation and study the results.

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