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Optimization of Badak LNG Inventory Planning Management Based on Forecasted Demand

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ABSTRACT
In the process of producing LNG, Badak LNG performs Maintenance, Repair, and Overhaul (MRO) activities to ensure the reliability, safety, and productivity of the facilities equipment. Currently, the equipment required to produce LNG products is less in numbers due to the decreasing upstream feed gas supply. This condition has brought a massive challenge for the company to reduce the inventory value. The effort had been started since 2014 by implementing write-off and impairment strategy for the obsolete and dead stock spare parts. It has successfully decreased the value, yet the value has not reached the allowable level. According to best practice released by the Society for Maintenance and Reliability Professionals (SMRP), the allowable inventory value to support MRO activities is typically set as 1.5% of Replacement Asset Value (RAV). In the case of Badak LNG, to achieve that level, the inventory value should be reduced by USD 5.5 million. Departing from this target, the company is now attempting the reduction through the forecasting process improvement. Based on the calculations, forecasting process improvement can afford an approximately USD 4.56 million reduction, but it is only 82.90% of the target value of reduction. The remaining value should be eliminated through the implementation of write off and impairment strategy to the available obsolete and dead stock spare parts. In addition, to prevent the additional dead stock items in the future, replenishment strategy for the other spare part categories including insurance, repairable, and replacement parts should be differentiated from consumable parts.

Keywords: *Badak LNG, MRO, inventory, RAV, write-off, impairment, forecasting*

1. INTRODUCTION

Badak LNG is a world class energy company that has plant facilities to produce Liquefied Natural Gas (LNG). It has 8 (eight) LNG process trains (A-H) completed with Utilities and Storage Loading facilities that were fully operated until 2012. In the process of producing LNG, Badak LNG performs Maintenance, Repair, and Overhaul (MRO) activities to ensure reliability, safety, and productivity of the facilities equipment. The activities require the availability of the spare part in the Warehouse to support the operational of LNG processing plants.

To ensure the spare part availability when required, Badak LNG applies a stock replenishment strategy based on Minimum and Maximum level or further called as Min-Max level. Minimum level is defined as the Reorder Point (ROP) that initiates reorder process of spare parts and Maximum level is defined as the maximum allowable quantity of spare parts stored. The Min-Max level is determined through the forecasting of spare part demand with Simple Average method. The method uses the average number of previous 5 (five) years demand of the spare parts to forecast the future demand and the result is referred to as the reference to calculate the Min-Max level. This Min-Max level will further determine the quantity of spare parts ordered, determine the available spare parts stored in the Warehouse and result in the inventory value. This value has been attempted to be reduced since the changing of trains operation mode in the year of 2013. From 2013 until 2014 there were only 6 LNG process trains operated, 2 LNG process trains were put in long term idle, while from 2015 until 2019 there were only 5 LNG process trains operated to produce LNG, and currently there are only 3 LNG process trains operated in 2020. This change has become a challenge for the company to reduce the inventory value.

Some efforts had been started since 2014 by implementing write-off and impairment strategy to eliminate the value of obsolete parts and dead stock spare parts. It has successfully decreased the inventory value yet the quantity of the dead stock spare parts is still higher from time to time. These dead stock items were coming from the unutilized spare parts that are ordered based on the forecasted demand calculated by Simple Average method. This method is applied to all spare part categories including insurance, repairable, and replacement parts and there is no error measurement and comparison with the other forecasting methods to confront the result. Accordingly, this strategy has led to the additional dead stock items and brings a struggling condition for the company to reach the allowable value.

Departing from this problem, this paper will introduce the new reduction effort through the forecasting process improvement as it is a factor that determines the Min-Max level and might affect the inventory value. The study for this improvement has never been introduced to the company since there are only write off and impairment strategies implemented to reduce the inventory value during the years. The research in this paper is introduced to the company with the following intention:

a. Find the attainable inventory value reduction through the forecasting process improvement with 100% accuracy of forecasting results.
b. Find the remaining value to be reduced to achieve the allowable inventory level

2. LITERATURE REVIEW

Based on maintenance standard practices developed by the Society for Maintenance and Reliability Professionals (SMRP), the allowable inventory value of spare parts to support MRO activities should be referred to the Replacement Asset Value (RAV), which is typically set as 1.5% of RAV [1]. RAV is defined as the cost that will be incurred to replace the facility and equipment in its current configuration based on current replacement prices [2]. Since Badak LNG runs MRO activities to produce LNG products, this SMRP standard practices will be referred to as the reference in this paper to study the improvements that could be taken to achieve the allowable inventory value. In case of Badak LNG, the RAV was calculated on the basis of 3 LNG process trains operation mode and it gives the number of USD 1.5 billion. Therefore, the overall inventory value should be 1.5% of 1.5 billion USD that equals to USD 22.5 million. In fact, in the year of 2019, the overall inventory value from all stocked items still in the level of USD 28 million, it exceeds USD 5.5 million from 22.5 million USD of the target value.

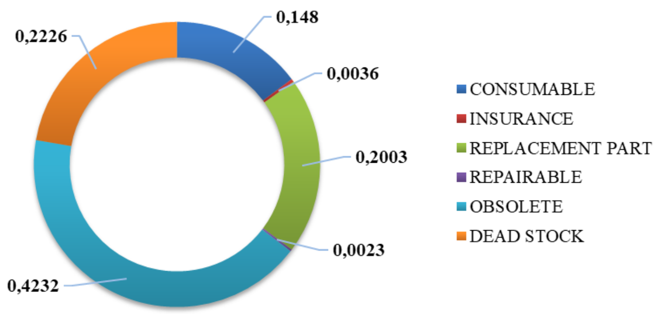

Figure 1 Spare part categories percentage

Table 1. Main Warehouse Spare Part Categorization

Categories	Definitions
Consumable	Disposable part which is routinely utilized in normal days.
Insurance	Spare parts recommended to be put in stock by manufacturer because the unavailability could cause significant process disruption when the equipment breaks down
Replacement Part	Spare parts that have a schedule to be replaced, such as 2 years and 4 years.
Repairable	Spare parts that can be repaired and put back to stock in the warehouse once the repair is completed.
Obsolete	A type of spare part that has lifetime because it has passed the usage limit, outdated from technology point of view, or not produced anymore.
Dead Stock	The items which have not been used in 15 years or even more.

3. RESEARCH METHODOLOGY

Spare parts stored in the warehouse are defined as stock items and identified based on stock numbers. These stock items are used for MRO activities covering several craft items including Instrumentation, Electrical, Mechanical Rotating, Mechanical Static, Fire and Safety, Laboratory, Chemical, Oil, and General items. The items have been categorized into 5 (five) categories including consumable parts, insurance parts, replacement parts, repairable parts, obsolete parts, and the dead stock spare parts. The populations are pictured in Figure 1. Meanwhile the definitions of those categories are summarized in Table 1.

According to the definition stated in Table 1, forecasting process should only be applied to the consumable part categories due to these following reasons:

1. Consumable parts: the quantity required is fluctuating and the spare part is disposable since it cannot be repaired. Therefore, to maintain the

availability continuously, there should be a thorough forecasting process applied to predict the demand quantity.
2. Insurance items: The forecasting process is not applied to insurance items because it already has a certain recommended quantity that must be available when needed. Basically, the stock replenishment quantity is defined by the quantity recommended by the manufacturer. Therefore, there is no need to forecast the future demand of insurance items.
3. Replacement Part: The forecasting process should not be applied to the replacement part because the quantity supposed to be certainly quantified in certain periods, for instance in shutdown activities. Therefore, forecasting the quantity of replacement parts is not required.
4. Repairable items: These items must be available once repair activities are completed because it will be put back in stock. Therefore, there is no need to forecast the quantity of repairable items through a forecasting process.
5. Obsolete items: There is no need to apply forecasting and stock replenishment process to obsolete items because the items will no longer be used in the future.
6. Dead stock items: These items should not be replenished because the available parts have not been used in 15 years or even more. Hence, forecasting should not be applied to these items.

Forecasting process should only be applied to consumable items through these following steps:

1. Taking the samples from consumable parts
2. Forecast the demand using several the forecasting methods
3. Determine forecasting result from the best forecasting method
4. Compare the forecasted demand with the actual demand in 2019
5. Calculate new Min-Max level from the items which result the accurate demand
6. Calculate the inventory value reduction from the new Min-Max level

3.1. Step 1: Samples Taking from Consumable parts

In 2019, in total, there were 6,950 consumable items with the detail shown in the Table 2. As a pilot project, the samples will be taken from instrumentation parts covering 530 line-items.

Table 2. Detail Consumable items

No	Stocked Items	Quantity (Items)	Value (USD)
1	Mechanical Rotating	2,768	3,368,653.16
2	Mechanical Static	2,232	2,294,900.56
3	Instrumentation	530	656,803.72
4	Electrical	853	646,831.76
5	Fire & Safety	38	138,134.58
6	Laboratory	96	75,160.44
7	Chemical	46	1,515,415.04
8	Oil	18	42,294.29
9	General	369	108,843.04
TOTAL		**6,950**	**8,847,036.59**

3.2. Step 2: Forecast the Demand

Currently the company only uses the Simple Average method to forecast the demand. In fact, it has increased the dead stock spare parts because there is no error measurement and comparison with the other methods to confront the results. Therefore, in this paper, the forecasted demand will be calculated using 10 (ten) forecasting methods to get the comprehensive comparison of the results. The demand is forecasted only based on the historical spare part demands from 2014 to 2018 without considering equipment failure data. The methods used in this paper including:

1. **Naïve**, future demand is considered the same as the last demand.
2. **Simple Average**, future demand is the average value of the previous period of demand.
3. **Moving Average**, future demand is obtained from average demands in a certain length of previous periods.
4. **Exponential Smoothing**, future demand is obtained by weighting the historical demand by the weighted constant α (where $0 \leq \alpha \leq 1$).
5. **Linear Regression,** future demand is approached by a trend of historical demand and it is obtained from a single dependent variable (in this case it is the installed based quantity).
6. **Doubled-Linear Regression,** future demand is approached by trend of historical demand and it is obtained from double dependent variables (x1 is installed based quantity and x2 is time), and n is the number of periods.
7. **Naïve with Trend,** the future demand is obtained from the sum of demand in last period and previous data series of demand.
8. **Holt's Method (Double Exponential Smoothing),** the future demand is obtained by approaching a data trend with two exponential parameters γ, α ($0 \leq \alpha \leq 1$; $0 \leq \gamma \leq 1$).
9. **Croston,** the future demand is obtained from division of demand size and interval time of demand.

10. **Synthetos Boylan Approximation (SBA),** future demand is obtained from division of demand size and interval time with the estimation factor. [3]

3.3. Step 3: Select the best forecasting method

The best forecasting method would be selected by comparing the possible errors that might be given by those methods. The error is calculated from the forecasted demands given by the methods. The best forecasting result is selected from the method that would give the smallest possible error among other methods. There are some known error measurement methods such as Mean Absolute Deviation (MAD), Mean Absolute Percentage Error (MAPE), and Mean Squared Error (MSE) [3]. MAD would be less effective for data that has very high and low demand because the formula would average the demand to forecast the error, so that despite the formula gives small error but the demand might give big variance from the future demand. MAPE is less effective for the data that has zero demand because the formula would give an undefined number. Meanwhile the MSE is applicable to various data variations and the data with zero demand because it squares the error so that it would not result in an undefined number. Therefore, in this paper, MSE is more preferable to be used to predict the possible error of the forecasting results.

3.4. Step 4: Comparison with Actual Demand in 2019

The forecasted demand of each item is then compared with the actual demands made in 2019.

3.5. Step 5: Calculate the New Min-Max Level

Based on the company existing work instruction [4], Min-Max level is calculated through following formula:

$$\mathrm{Min} = (\mathrm{LT\ x\ MU}) + \mathrm{SS} \quad (1)$$

$$\mathrm{Max} = ((\mathrm{LT\ xMU})\mathrm{x\ CF}) + \mathrm{SS} \quad (2)$$

Lead time is defined as the length of the time between the Purchasing Request (PR) creation date until payment date. Lead time is obtained based on manufacturer areas. For instance, the lead time for spare parts purchased from domestic areas in Indonesia is set for 2 months, spare part purchased from Singapore is set for 3 months, and spare part purchased from Houston is set for 6 months [4]. In fact, the lead time of the spare parts purchased must be varying. Therefore, lead time should be obtained from the actual average lead time of previous orders (LT_{avg}). Meanwhile average monthly usage (MU) is

Table 3. Summary of SS and CF score

Categories	Definition	CF	SS
CEC-1	Critical for and associated with production and safety (occupational and process)	2	2 x average monthly usage
CEC-2	Associated to production supporting equipment	2	2 x average monthly usage
CEC-3	Used in the plant but not directly related to production	1.5	1 x average monthly usage
CEC-4	Critical for health and safety but it is not associated with plant	1.5	1 x average monthly usage
CEC-5	Non-critical material – not associated to plant/production	1	Not Required

calculated from the annual forecasted demand that is expressed with the following formula [4]:

$$\mathrm{MU} = \frac{\text{Annual forecasted demand}}{12} \quad (3)$$

SS is the abbreviation of Safety Stock. It is the additional quantity that should be maintained available to prevent stockout in the period of waiting for the new ordered spare parts. In addition, CF or Correction Factor is another parameter considered in Min-Max level calculation. Both SS and CF are scored based on the criticality of an equipment which is represented by Criticality Endangered Category (CEC) including CEC 1, 2, 3, 4, and 5. This criticality is measured from its association with plant production, occupational health and safety, and process safety [5]. SS for spare parts with criteria of CEC-1 and CEC-2 is more than SS for CEC-3, CEC-4, and CEC-5 since CEC-1 and CEC-2 are more critical to production. The CEC definition and its associated SS and CF are shown in the Table 3.

3.6. Step 6: Calculate the inventory value reduction

The inventory value reduction is afforded through the reduction of Min-Max level because the Min-Max level reduction would impact the spare part on-hand quantity stored in the Warehouse. The lower quantity of maximum level results in less expense while the lower minimum level will shift the order time so that it will shift the expense in the next period as seen in the Figure 2.

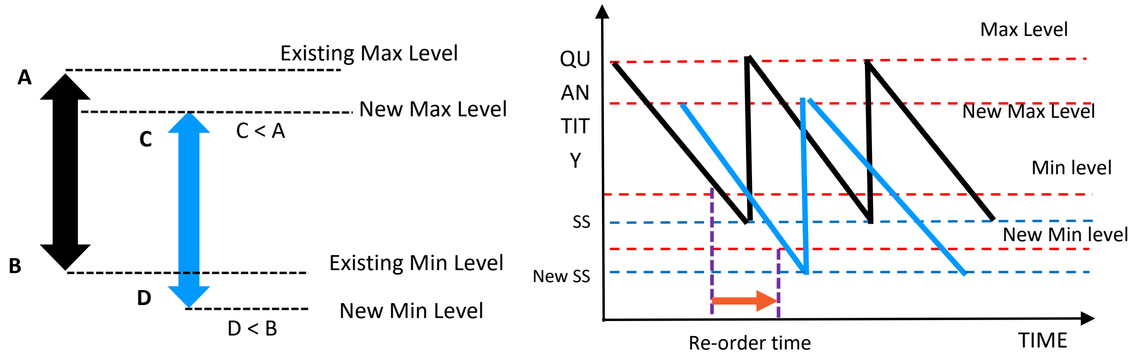

Figure 2. Min-Max level reduction

4. RESULTS

The forecasting calculation of spare part demand requires several preliminary data. It includes actual spare part demand in the previous 5 (five) years, running basis of LNG process train, and installed based quantity (IBQ) of the spare part. For example, stock code number 347690 is provided with the required preliminary detail shown in Table 4 below and based on the data provided, the future demand is calculated using the 10 (ten) forecasting methods. The forecasted demand results from all forecasting methods are summarized in the Figure 3.

Table 4. Preliminary Data of Sample

Stock Code No	347690		
Description	RING; PISTON ACTUATOR; FOR CONTROL VALVE		
Year	**Running Train Basis**	**Actual Demand**	**Installed Base Quantity (IBQ) (Unit)**
2014	6	2	222
2015	5	0	210
2016	5	1	210
2017	5	0	210
2018	5	2	210
2019	5	?	210

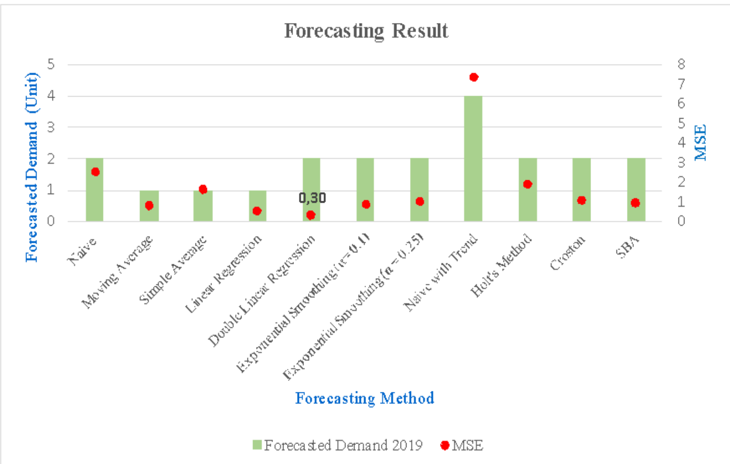

Figure 3. Example of Forecasting Result

As seen in Figure 3, the double linear regression method gives the smallest MSE among other methods, therefore the result is chosen as the forecasted demand, which is 2 units. Similar steps are subsequently applied to all 246 samples and the results are compared with the actual demands in 2019. Based on the comparison, there are 3 (three) states of forecasting result of each items:

A. The forecasted demand is higher than the actual demand

B. The trend of high demand in the previous 5 years period gives a result of the high forecasted demand in 2019. However, in fact, the demand in 2019 is lower than calculated. It is observed that there was less material demand for Corrective Maintenance activities in 2019 than in the previous 5 years period.

C. The forecasted demand is the same as actual demand

ince the demand in the previous 5 years period
ıd in the year of 2019 were relatively stable, the
ɔrecasted demand results in the same quantity as
ıe actual demand in 2019.
he forecasted demand is higher than the actual
emand
ı contrast to the state A above, in this state it was
ɔund that there were higher spare parts demand
sed for Corrective Maintenance activities in
019 than in the previous 5 years period.

; a result, there are 33.39% or 177 line-items out
) instrument consumable items that give 100%
ıcy, it is 14.34% better than if the company uses
e Average method only. Min-Max level
ıtion was carried out only to those 178 items
since the forecasted demand of the other 353 items are not the same as the actual demand, so the evaluation

Table 5. Attainable Value Reduction of Forecasting Process

No	Consumable Craft Items	Quantity (Line Items)	Value (USD)	Items with 100% Accuracy	Value Reduction (USD)
1	Instrumentation	530	656,803.72	177	339,269.96
2	Mechanical Rotating	2,768	3,368,653.16	924	1,740,067.52
3	Mechanical Static	2,232	2,294,900.56	745	1,185,423.89
4	Electrical	853	646,831.76	285	334,118.97
5	Fire & Safety	38	138,134.58	13	71,353.99
6	Laboratory	96	75,160.44	32	38,823.90
7	Chemical	46	1,515,415.04	15	782,783.02
8	Oil	18	42,294.29	6	21,846.99
9	General	369	108,843.04	123	56,222.54
TOTAL		**6,950**	**8,847,036.59**	**2,320**	**4,569,910.64**

on existing Min-Max level to those items would not be necessarily required. As a result, Min-Max level reduction from instrumentation consumable parts can afford USD 339 thousands value reduction.

5. DISCUSSION

As mentioned previously, in the year of 2019, there was an excessive of USD 5.5 million to reduce from the overall inventory value. This excessive value will be eliminated through the forecasting process of consumable items. Based on the result of the samples taken from Instrumentation parts, there are only 33.39% or 177 line-items out of 530 instrument consumable items that give 100% forecasting accuracy.

Furthermore, to find the possible reduction obtained from other crafts, it is assumed that forecasting result of the other crafts (rotating mechanical, static mechanical, electrical, fire and safety, chemical, oil, and general items) would result the same percentage items that give 100% accuracy, the reduction obtained from those other craft items can be estimated through linear regression by assuming that Min-Max level reduction of each line-items would give the same value reduction. The summary of attainable value reduction is shown in the Table 5 below.

As seen in Table 5, the total value reduction obtained from forecasting process improvement of all consumable items will be approximately USD 4.56 million, 82.90% of the value reduction target, USD 5.5 million. There are still USD 940 thousand remaining and this remaining excessive value should be eliminated through the write off and impairment

strategy of the 42.32% of obsolete parts and 22.26% of dead stock spare parts. Write off strategy is applied to reduce the value contributed from dead stock spare parts, while impairment strategy aims to reduce the value contributed from the dead stock spare parts. Write-off is the strategy in which the value of the spare parts is eliminated from the inventory system and physically the spare part is taken out separately from other spare parts and it cannot be further used by custodians. Meanwhile impairment is the strategy in which the value of the spare parts is eliminated from the inventory system but physically, the remaining available spare parts are still put in the existing locations and it still can be used by the custodians.

Furthermore, to prevent the additional dead stock spare parts in the future, the stock replenishment strategy of other part categories including 0.36% of insurance parts, 0.23% of repairable parts, and 20.03 % of replacement parts should be differentiated from consumable parts. Nowadays the replenishment strategy of those categories is treated equally with consumable parts whilst based on the definition, there should be different strategies applied to those categories.

Nevertheless, the replenishment strategy improvement for insurance and repairable parts would not be more impactful to eliminate the dead stock items since they have a smaller population than the others. Therefore, there should be more attention to 20.03% of replacement parts. The replenishment strategy applied to replacement parts should be just in time strategy because replacement parts are used for the scheduled maintenance activities only such as shutdown and overhaul program. Therefore, instead of continuously replenishing the spare parts in normal days, they should only be ordered when required for a specific scheduled program and should be utilized exactly the same with the ordered quantity so that

Table 6. Strategy for Dominant Categories

Category	Strategy
Consumable	Forecasting Improvement
Replacement Part	Just in Time (JIT)
Obsolete	Write off
Deadstock	Impairment

there would be no spare parts remaining in the inventory after the scheduled program finished. To summarize, the strategies applied for the other categories are shown in Table 6.

6. CONCLUSION

1. Forecasting process improvement discussed in this paper applies the forecasting methods that use historical data of spare part demand as the variable to forecast the future demand. As a result, with 100% accuracy, forecasting process improvement using those methods can reduce the inventory value by approximately USD 4.56 million, only 82.90% of the target value reduction. To afford a better result, the future spare part demand could be forecasted through a different method approach using the variable of equipment failure record.
2. There is still USD 940 thousand remaining to be reduced to achieve the allowable level. This remaining value should be eliminated through the implementation of write off and impairment strategy to the available obsolete and dead stock spare parts.

AUTHORS' CONTRIBUTIONS

As this paper is arranged by a single author referred to by the name above, the author did all the job necessary to finish this paper, including conceiving the idea, collecting the data, verifying the data, performing calculation and analysis, and writing the manuscript.

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