

The Application of Industrial 4.0 Assets Maintenance Strategy to Improve Productivity Level at Energy Industry Customers

Muhammad Fikri¹, Widhyawan Prawiraatmadja²

School of Business and Management Institut Teknologi
Bandung, Indonesia
Email: m.fikri@sbm-itb.ac.id

ABSTRACT

The productivity level at hydrocarbon processing and energy companies can be affected by unplanned shutdown of assets which leads to significant business loss such as lost production, wasted labor, depleted inventory, and higher exposure to safety risks. As an energy company, unplanned shutdowns could cause another multiplier negative effect aside from financial and operations. It would take days or weeks for the markets to adjust to the sudden loss of the production, resulting the price impact and scarcity of hydrocarbon products in the market would impact the nation's economy and potentially create a political disturbance.

This journal scope would discuss on the unplanned shutdown as the main business issue and how the proposed Industry 4.0 technology solutions on preventing the causes and explanations to transform the current company operations to improve the productivity. The proposed solutions can be acquired by an energy company as a reference to enhance its existing assets maintenance strategy to be a part of improvement process. There are three companies which are included as part of the journal assessment; Company A (Fluid Catalytic Cracking), Company B (Geothermal Power Utility), and Company C (Liquified Natural Gas Plant).

Keywords: unplanned shutdown, productivity improvement, assets maintenance strategy.

Introduction

Background

Disrupted operations caused by unplanned shutdown of assets at hydrocarbon processing and energy companies lead to significant business loss such as lost production, wasted labor, depleted inventory, and higher exposure to safety risks. As a refining company, unplanned shutdowns could cause another multiplier negative effect aside from financial and operations. It would take days or weeks for the markets to adjust to the sudden loss of the production, resulting the price impact and scarcity of hydrocarbon products in the market would impact the nation's economy and potentially create a political disturbance.

This journal scope would discuss on the unplanned shutdown as the main business issue and how the proposed solutions on preventing the causes and explanations to transform the current company operations to improve the productivity. The proposed solutions can be acquired by a refining company as a reference to enhance its existing assets maintenance strategy to be a part of improvement process. There are three companies which are included as part of the journal assessment; Company A (Fluid Catalytic Cracking), Company B (Captive Power Utility), and Company C (Liquified Natural Gas Plant). The scope of this journal is defined as:

- (1) To determine the risks of not having reliable and robust maintenance strategy and its direct or indirect impact on the unplanned shutdown. To define the cost of downtime. To determine the downtime cost which consists of the tangible cost of lost revenue, labor costs and costs of excess capacity plus the intangible cost. (Mathematical Model on Criticality Ranking Assessment)
- (2) How to assess company internal existing assets maintenance strategy and its in-house capability, including its adaptability and tendency to transform the operations. (Framework: Buy-Borrow-Build)
- (3) Determine the gap of ideal maintenance practice by using several best practice references in the industry by the top performers. (Reference Study)

- (4) Leverage the Industrial 4.0 predictive maintenance technology to achieve the ideal condition of the operations in order to increase the company productivity and reduce the total cost ownership. Finding the optimum point between interval and scope to improve the maintenance effectiveness (Framework: Improved Risk Priority Number, Financial Saving)
- (5) The implementation & recommendation for customers on how to transform the existing maintenance strategy and its relation to overall company performance and competitive advantages. Implementation segment would cover three aspects of the strategy: people, process, and technology. (Calculation: Return of Investment including financial implication and cost justification)

Problem Formulation

Machinery assets are required to be maintained in certain period of time to ensure that it can be operated in the optimal condition. Typically, shutdown maintenance is required as the work can only be done while the assets are not in use. Shutdown of machinery can create a significant financial cost however it is necessary to be taken due to the deuteration nature of the defective parts. This type of shutdown normally be called as planned shutdown which has the objective to perform certain set of maintenance work in order to ensure the assets' lifetime and its performance.

Unlike planned shutdown, unplanned shutdown happens due to unexpected machinery breakdown due to assets' subsystem, personnel error, or hazardous incident which would have had unsafe consequences without shutdown. Unplanned shutdown can be driven either automatically by assets' shutdown trip system or manually by the operator. Not only that unplanned shutdown has the direct impact to the company production, it also can act as the benchmark indicator of how well the maintenance practice is done. It is critical for the operator to understand the root cause problem of the unplanned shutdown, determine the corrective action to be executed, and bring back the asset to run to avoid further loss due to missing of production.

As the refining process is considered as complex system, most of the time the causes of unplanned shutdown were not captured properly as the 89% of machinery breakdowns happened in the random mode. The proper way to reduce the unplanned shutdown is to improve the maintenance practice and strategy as well as improving the company competencies to capture and analyze the root cause problem of the shutdown.

Business Issue and Objective

The business issue and objective which is raised and analyzed in this journal as below.

- Business Issue: Disrupted operations caused by unplanned shutdown of assets at energy companies lead to significant business loss such as lost production, wasted labor, depleted inventory, and higher exposure to safety risks.
- Objective: To describe/analyze on how Industrial 4.0 application can improve assets maintenance strategy to prevent unplanned shutdowns which will improve of company's productivity

Questions to be answered

Below is the list of questions to be answered as part of the end result of this study.

- How much is the cost of downtime due to unplanned shutdown?
- How capable the internal company resources to run its own maintenance strategy in order to avoid/eliminate the risk of unplanned shutdown?
- How to implement the industrial 4.0 technology to improve the existing assets maintenance strategy to prevent future unplanned shutdown?

- How much big is the benefits in adopting the industrial 4.0 technology versus the cost of investment?

Business Issue & Conceptual Framework

This part discusses on several conceptual framework which are used to develop the solution on the business issue of the journal. The first section of this part discussed focusing on how digitalization can be offered to develop the improved maintenance strategy which delivers operational excellence, cost optimization, safety improvements, efficient workforce, and knowledge preservation. Second section explains on the basic of maintenance program, the philosophy and strategy, assets management, and how to shift the paradigm from reactive approach into proactive reliability-centered maintenance. The third section describes on how the combination of the digital tools and organization strategy transform into new operating model that improve the overall plant productivity. Total cost of maintenance is one of the factors to be considered other than productivity to evaluate the success level of the transformation.

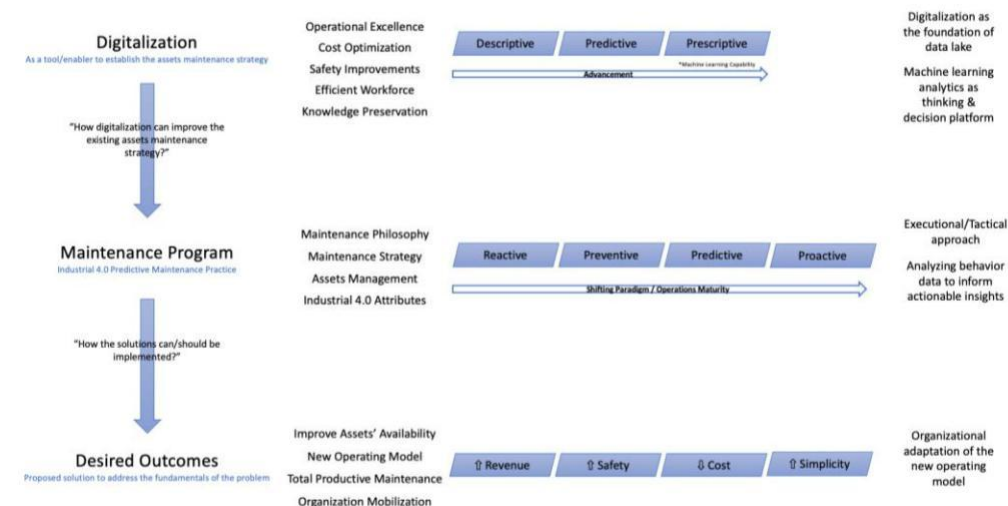


Figure 1. Conceptual framework to develop business solutions consisted of digitalization, maintenance program, and desired outcomes.

Methodology

In this journal, there are three companies that had been assessed by looking into existing assets and their internal maintenance practice. Those three companies are of Company A (FCC), Company B (Utility Power Plant), and Company C (LNG Plant). The reason of using the sampling of those three companies due to the their operations are heavily rely on prime mover as the primary assets. The qualitative workout session were conducted in order to obtain the data as explained in the Appendix A3. The main objective of the workout session is to achieve two sets of information; the assets scoping which determine the object of maintenance activities, and the internal capability, which determine the subject of maintenance activities.

Using the provided data, the analysis is carried out using the methodology and framework to translate the qualitative data into measurable quantitative data. Below are scope and methodology / framework which are carried out for this journal.

#	Project Scope	Methodology/Framework
---	---------------	-----------------------

1	Determine the cost of downtime due to unplanned shutdown	Mathematical Model on Criticality Ranking Assessment
2	Assessment on company internal existing assets maintenance strategy and its in-house capability	Buy-Borrow-Build
3	Determine the gap between existing operations with the ideal maintenance practice in the industry	Reference Study
4	Selecting the right Industrial 4.0 technology to improve the existing or enable predictive maintenance practice	Improved Risk Priority Number, Financial Saving Calculation
5	Analysis on the solutions implementation and providing the recommendation through simulated numbers	ROI calculation and cost justification

Table 1. – Journal scope and methodology

Method of Data Collection and Analysis

This part of the journal explains business solution and recommendation to improve the overall maintenance strategy effectiveness. There are four steps in the journal, encompass of:

- (1) Assets scoping; to understand the scale of the assets including the risk which are attributed to it. To understand the potential loss due to disrupted operations due to unplanned shutdown of machinery assets.
- (2) Internal capability; to understand the current internal company capability on the maintenance strategy and how to optimize the current practice by optimizing the interval and scope of maintenance, in-house vs. outsourcing decision, and organization redesign
- (3) Gap assessment: to benchmark with the industry top performers on how the maintenance strategy could be run, providing the recommended corrective actions and strategy, and calculate the financial savings using the improved risk priority number method.
- (4) Implementation: to apply the right technology following by organization mobilization to fit with the proposed solution. To provide the return of investment (ROI) calculation and financial implication

and cost justification by adopting the improved assets maintenance strategy using industrial 4.0 predictive maintenance.



Figure 2 – Four steps of journal on how developing the scope, assessment, and implementation.

The data that used in this journal are engineering ones based on the interview performed and only used for this journal purposes. The template of calculation is solely developed for this journal including the financial numbers reflect the measurement of cost of risk.

Assets Risk Criticality Ranking Assessment

The first task of the solution is to quantify the maintenance objects based on its criticality. The Risk Priority number (RPN) method is used to develop the criticality ranking of assets. Risk Priority Number (RPN) is found by multiplying the occurrence index by the severity index and the detection index. The purpose of the critical ranking list is to describe the whole scope of assets and to optimize the planning of maintenance resources. Table 3.1 describes the example of Criticality Ranking based on RPN.

#	Assets	Severity (Consequences) Index			Occurrence Index	Detection Index	RPN
		Prod.	Env.	Safety			
1.	Gas Turbine Generator	8	6	6	0.1	0.85	1.7
2.	Steam Turbine Generator	7	4	5	0.15	0.7	1.68
3.	BOG Compressor	8	5	4	0.2	0.4	1.36
4.	Boiler Feedwater Pump	5	4	3	0.15	0.45	0.81
5.	Cooling Tower Fans	4	3	2	0.05	0.6	0.27

Table 2 – Criticality ranking table based on Risk Priority Number (RPN)

Severity (consequence) index can be determined by using weight balancing method of 7 parameters of failure consequences covering: Health, Safety, and Environment (HSE), regulatory compliance, production/operating impact, product quality, assets replacement value, spare parts lead time, and planned utilization rate. The higher the RPN number means that the asset has a higher risk.

Furthermore, severity index also can be determined whether the asset has any redundancy in the event of failure, as such, the unavailability of the function will impact the total plant shutdown. For example, a large gas turbine compressor is used in the fluid catalytic cracker (FCC) at a refinery, normally does not any stand by spares considering high investment capital cost to build a redundant system would delay the return of investment (ROI) of the project.

Evaluating the Risk Priority Number

RPN method is essential to determine the improvement factor which is used to quantify the risk and cost of the proposed solutions. It helps the company to determine the priority ranking of the resources assignment as well as to translate the risk into quantitative figure such as dollar value. The table 5 is table which is used for RPN assessment for Company A – Fluid Catalytic Cracking (FCC).

No.	Assets	Original					
		Severity (Consequences) Index			Occurrence Index	Detection Index	RPN
		Prod.	Env.	Safety			
1	Steam Turbine Generator A (50 MW)	8	6	6	0.1	0.85	1.7
2	Steam Turbine Generator B (50 MW)	7	4	5	0.1	0.7	1.12
3	Steam Turbine Generator C (50 MW)	8	6	6	0.1	0.4	0.8
4	Wet Gas Compressor	6	8	3	0.05	0.45	0.3825
5	Main Air Blower	7	3	3	0.33	0.6	2.574
6	Heat Pump Compressor	5	7	4	0.05	0.45	0.36
7	Recycle Gas Compressor	7	8	5	0.25	0.6	3

Table 3 – RPN table for Company A (FCC).

As explained in Table 5, the highest RPN comes from Main Air Blower, with the attributes of not having redundant system, and have high level of shutdown occurrence index at 0.33 point. This create potential of risk in terms of the cost to the company. To quantify the economic impact of the risk, two components are used in the RPN:

- (1) Annualized Aggregated Asset Contribution to Production; the amount of money that one asset contributes into the production train of the company.
- (2) Annualized Maintenance Cost; the amount of money spent in order to maintain the assets, annualized into yearly cost.

Annualized aggregated asset contribution can be determined by looking into assets' role in a single train of production. For example, if the asset is non-operational, how big or how much the opportunity loss during the period of unavailability. The amount then calculated in annual/yearly basis using the NPV model. Annualized maintenance cost is derived from total maintenance cost of overall asset's lifetime. The total asset maintenance then annualized using NPV model to get the annualized amount. Every asset has different annual maintenance cost, for example major turnaround will be very costly compare

with ordinary pitstop shutdown. Table 6 describes the example the both of cost on each asset of FCC plant.

No.	Assets	Annualized Aggregated Asset Contribution to the Production	Annualized Maintenance Cost (USD)
1	Steam Turbine Generator A (50 MW)	17,520,000.00	2,000,000.00
2	Steam Turbine Generator B (50 MW)	17,520,000.00	2,000,000.00
3	Steam Turbine Generator C (50 MW)	17,520,000.00	2,000,000.00
4	Wet Gas Compressor	9,500,000.00	2,100,000.00
5	Main Air Blower	12,000,000.00	1,200,000.00
6	Heat Pump Compressor	79,000,000.00	1,800,000.00
7	Recycle Gas Compressor	7,500,000.00	1,450,000.00
	Total	160,560,000.00	12,550,000.00

Table 4 – Annualized aggregated asset contribution to the production and annualized maintenance cost for assets at FCC plant

Annualized aggregated asset contribution to the production is the profit parameter which defines the assets performance that drives the company profit. Annualized maintenance cost is the cost parameter which on the contrary, defines the assets fee that drives the company liability. Using the data provided from Table 5 and Table 6, the improvement strategy can be applied by developing the recommendation and corrective action to improve the RPN level which will improve the assets maintenance effectiveness to drive the cost lower.

Improved Risk Priority Number (RPN)

After implementing the recommended corrective actions, the improved RPN can be calculated to assess the cost of risks reduction and predicted assets availability improvement which are needed to be achieved. The RPN ratio or so-called Improvement Factor is calculated by dividing the improved RPN by old RPN.

$$\left(\frac{\text{Improved RPN}}{\text{Old RPN}} \right) =$$

The RPN ratio shall be lower compared with the old RPN to show that the recommended corrective actions are targeting the correct problem that causes the loss of production which is delivered by reducing the amount of unplanned shutdown.

Translating the Risk into Quantitative Financial Value

To have a result comparison of the recommended corrective outcomes of each asset, several indicators are used to translate the business risks into quantitative value.

(1) Annualized Aggregated Asset Contribution to the Production (AAACP)

This parameter indicates the how important the asset contribution to the production. For example, for utility power plant, the main turbine generator annualized asset contribution is the electricity production itself, since the unplanned shutdown the turbine generator will create total blackout of the production.

(2) Annualized Maintenance Cost (AMC)

The amount of money spent every year to maintain the cost. Since the maintenance cost is not always the same every year due to turnaround period of the assets, this parameter is annualized calculated to consider the net present value and asset lifetime.

(3) Annual Failure Probability due to Unplanned Shutdown (AFP)

The probability of the unplanned shutdown of the asset. The parameter can be achieved through historical record of the specific asset or can be retrieved of average MTBF/MTTR data from the industry. The annual failure probability is used to estimate the financial loss due to the risk of unplanned shutdown.

(4) Annualized Lost of Asset Contribution and Maintenance Cost due to Unplanned Shutdown (LDUS)

The amount of \$ loss due to unplanned shutdown as a result of multiplication of AFP and AAACP plus AFP.

LDUS is the parameter that translate the probability risk into possible financial consequences.

(5) Annual Saving or Translated Risk Cost Reduction (ASTR)

The amount of the financial result due to improved assets performance. The result of multiplication of LDUS and improvement factor (RPN ratio). LDUS number can be retrieved by multiplying AFP with the total amount of AAACP and AMC. LDUS amount represent the risk of financial loss of production and unused maintenance cost due to unplanned shutdown.

$$= \text{AFP} \times (\text{AAACP} + \text{AMC})$$

ASTR number is calculated by LDUS with the (1 – RPN Ratio). The ASTR is the indication of whether the improvement program is success or not.

$$= \text{LDUS} \times (1 - \text{RPN Ratio})$$

Proposed Business Solutions

This journal took three examples of the company as the data sample. Company A is a refinery which has Fluid Catalytic Cracking (FCC) the main process unit. Company B is a geothermal utility power plant consists of two units of power generation train. Company C is an LNG terminal which operates to liquify the natural gas and export through cargo ship delivery.

Company A (Refinery)

The operations nature of an FCC plant is to crack the oil feedstock most of the time is naphtha and convert it to more refined products such as high-octane component of gasoline. The first step to define the assets scoping and the original RPN value as shown in the table 5.

Define the recommendation and corrective actions in order to bring down the RPN of each asset.

No.	Assets	Recommendation and Corrective Actions
		Apply redundancy load distributed to three STG,

1	Steam Turbine Generator A (50 MW)	improve condition monitoring program, electricity outsourcing if steam production is sufficient.
2	Steam Turbine Generator B (50 MW)	Apply redundancy load distributed to three STG, improve condition monitoring program, electricity outsourcing if steam production is sufficient.
3	Steam Turbine Generator C (50 MW)	Apply redundancy load distributed to three STG, improve condition monitoring program, electricity outsourcing if steam production is sufficient.
4	Wet Gas Compressor	No redundancy can be made, improved condition monitoring program, develop in-house capability as the RPN is low
5	Main Air Blower	No redundancy can be made, improved condition monitoring program, outsource the maintenance practice when possible.

6	Heat Pump Compressor	No redundancy can be made, improved condition monitoring program, outsourcing is mostly not required.
7	Recycle Gas Compressor	No redundancy can be made, improved condition monitoring program, outsource the maintenance practice when possible.

Table 5 – Asset recommended corrective actions for assets at company A (FCC)

Calculate the improved RPN of each asset by multiplying the severity, occurrence, and detection index. The improved RPN number is obtained by estimating the reduction of risk if the recommended corrective actions are applied.

No.	Assets	Improved			
		Severity (Consequences) Index	Occurrence Index	Detection Index	RPN

		Prod .	Env.	Safety			
1	Steam Turbine Generator A (50 MW)	5	6	6	0.1	0.7	1.2
2	Steam Turbine Generator B (50 MW)	5	4	5	0.1	0.7	1
3	Steam Turbine Generator C (50 MW)	7	5	4	0.1	0.4	0.6
4	Wet Gas Compressor	6	8	3	0.05	0.3	0.3
5	Main Air Blower	7	3	3	0.33	0.55	2.4
6	Heat Pump Compressor	5	7	4	0.05	0.4	0.3
7	Recycle Gas Compressor	7	8	5	0.25	0.6	3

Table 6 – Improved RPN of each asset at Company A (FCC)

The improvement factor can be achieved by dividing the improved RPN with old RPN as shown in Table 7 below.

No.	Assets	RPN Ratio (Improvement Factor)
1	Steam Turbine Generator A (50 MW)	0.70
2	Steam Turbine Generator B (50 MW)	0.88
3	Steam Turbine Generator C (50 MW)	0.80
4	Wet Gas Compressor	0.67
5	Main Air Blower	0.92
6	Heat Pump Compressor	0.89
7	Recycle Gas Compressor	1.00

Table 7 – Improvement ratio of each asset at Company A (FCC)

The improvement ratio then is used to calculate the annual saving or translated risk cost reduction.

No.	Assets	Annualized Aggregated Asset Contribution to	Annualized Maintenance Cost (USD)	Annual Failure Probability due to Unplanned	Annualized Lost of Contribution and Maintenance Cost due to	Annual Saving or Translated Risk Cost
-----	--------	---	-----------------------------------	---	---	---------------------------------------

		the Production		Shutdown	Unplanned Shutdown	Reduction
1	Steam Turbine Generator A (50 MW)	17,520,000.00	2,000,000.00	4%	780,800.00	234,240.00
2	Steam Turbine Generator B (50 MW)	17,520,000.00	2,000,000.00	5%	976,000.00	122,000.00
3	Steam Turbine Generator C (50 MW)	17,520,000.00	2,000,000.00	4%	780,800.00	156,160.00
4	Wet Gas Compressor	9,500,000.00	2,100,000.00	7%	812,000.00	270,666.67

5	Main Air Blower	12,000,000.00	1,200,000.00	4%	528,000.00	44,000.00
6	Heat Pump Compressor	79,000,000.00	1,800,000.00	3%	2,424,000.00	269,333.33
7	Recycle Gas Compressor	7,500,000.00	1,450,000.00	3%	268,500.00	-
	Total	160,560,000.00	12,550,000.00		6,570,100.00	1,096,400.00

Table 8 – Calculation of annual saving or translated risk cost reduction using the RPN improvement factor method for Company A (FCC)

As shown in table 8, the potential of annual saving or translated risk cost reduction for Company A (FCC) is up to USD 1,096,400.00. This number is then used to justify the investment of the type of technology which can improve the total plant assets performance.

Using the same method as Company A, below is the annual saving calculation for Company B and C.

No.	Assets	Annualized Aggregated Asset Contribution to the Production	Annualized Maintenance Cost (USD)	Annual Failure Probability due to Unplanned	Annualized Lost of Contribution and Maintenance Cost due to	Annual Saving or Translated Risk Cost Reduction
-----	--------	---	--	---	---	--

				Shutdown	Unplanned Shutdown	
1	Steam Turbine Generator A (90 MW)	23,652,000.00	2,000,000.00	4%	1,026,080.00	221,311.37
2	Steam Turbine Generator B (100 MW)	26,280,000.00	2,000,000.00	4%	1,131,200.00	241,967.91
3	Hot Well Pump A	16,644,000.00	500,000.00	7%	1,200,080.00	600,040.00
4	Hot Well Pump B	16,644,000.00	500,000.00	7%	1,200,080.00	666,711.11
5	Cooling Tower Fan A	7,133,200.00	120,000.00	10%	725,320.00	60,443.33
6	Cooling Tower Fan B	7,133,200.00	120,000.00	10%	725,320.00	80,591.11
7	Cooling Tower Fan C	7,133,200.00	120,000.00	10%	725,320.00	-
	Total	104,619,600.00	5,360,000.00		6,733,400.00	1,871,064.84

Table 9 – Calculation of annual saving or translated risk cost reduction using the RPN improvement factor method for Company B (Utility Power Plant)

As shown in table 9, the potential of annual saving or translated risk cost reduction for Company B (Power Plant) is up to USD 1,871,064.84. This number is then used to justify the investment of the type of technology which can improve the total plant assets performance.

No.	Assets	Annualized Aggregated Asset Contribution to the Production	Annualized Maintenance Cost (USD)	Annual Failure Probability due to Unplanned Shutdown	Annualized Lost Contribution of an Maintenance Cost due to Unplanned Shutdown	Annual Saving or Translated Risk Cost Reduction
1	Gas Turbine Generator A			4%		

	(50 MW)	13,140,000.00	2,500,000.00		625,600.00	196,266.67
2	Gas Turbine Generator B (50 MW)	13,140,000.00	2,500,000.00	5%	782,000.00	130,333.33
3	Gas Turbine Generator C (50 MW)	13,140,000.00	2,500,000.00	4%	625,600.00	(286,733.33)
4	LNG Loading Pump	22,500,000.00	2,100,000.00	7%	1,722,000.00	673,826.09
5	LNG Liquid Return Pump	12,000,000.00	1,750,000.00	6%	825,000.00	144,375.00

6	Refrigerant Compressor	49,000,000.00	2,500,000.00	5%	2,575,000.00	413,271.60
7	Mixed Refrigerant Compressor	33,000,000.00	2,250,000.00	5%	1,762,500.00	352,500.00
8	BOG Compressor	44,000,000.00	1,850,000.00	2%	917,000.00	264,911.11
9	Air Fin Cooler	1,250,000.00	450,000.00	7%	119,000.00	19,833.33
	Total	201,170,000.00	18,400,000.00		9,953,700.00	1,908,583.80

Table 10 – Calculation of annual saving or translated risk cost reduction using the RPN improvement factor method for Company C (LNG Plant)

As shown in table 10 the potential of annual saving or translated risk cost reduction for Company C (LNG Plant) is up to USD 1,908,583.80. This number is then used to justify the investment of the type of technology which can improve the total plant assets performance.

Results and Discussion

A return of investment (ROI) calculation is required to justify the investment of the new asset maintenance strategy. Not only because it provides a strong rationale, it is also easy to understand by most of operating company leadership. Most of the new Industrial 4.0 technology relies on the software system that process the data of the assets automatically. However, energy companies' assets mostly have the lifetime span of 4-25 years, and this condition requires additional hardware to be installed such as instrumentation sensors and network peripheral devices.

Once the sensors are connected to the machinery assets, the network system should be developed to collect all the measurement data and bring them all to the single software platform in such communized database (CBD) data format. This requires complete set of Operations Technology (OT) network that can also be connected to business or enterprise level network. Coupled with the network system, there is a CMMS system that record all maintenance plan and practice that has been performed. Those two system CMMS and Communized Database then connected to establish a data lake. Figure 6 explains the complete digitalization to improve the overall maintenance decision-making process.

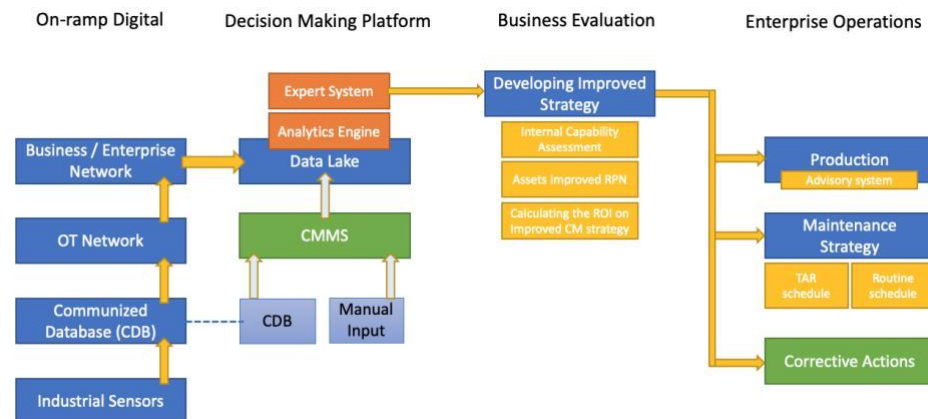


Figure 6– Business process of adopting Industrial 4.0 technology in the assets maintenance strategy

Once the data lake is established, the analytics engine can be installed on top of it. The purpose of analytics engine is to assist the human operators to develop an expert system. An expert system is a computer-run artificial intelligence technology that emulates the decision-making ability of a human expert. Since there are thousands of data point to be analyzed in the same time stamp, it is difficult to run a such calculation without the support from expert system. The expert system type of investment can be vary depending on the needs of the company requirement and business profile.

In the manpower side, the new business model of asset maintenance strategy may require new headcounts to be hired. Most of the time, new hired headcounts are specialists who has a sets of domain expertise to improve the maintenance effectiveness. The existing manpower can be also utilized and need some skillset to be trained. The model that use most of manpower to do recurrent job should be improved to be on more value adding ones. The company should put more focus on analysis and decision-making type of job instead of recursive practice ones such as data collection or administration type of work.

The third kind of investment on the process side. The industrial 4.0 technology relies on the system that works by cross correlating on between process parameter to determine the early signs of asset breakdown. The architecture requires the operations to be centralized as well as the established of an integrated data center. Centralized operations would be much preferred compared with scattered ones as it will build the domain expertise and knowledge much faster. Also the expert system which relies on analytics engine will sit on the centralized system.

Table 11 below describes the typical investment cost on each investment of technology, manpower, and process on each energy Company A, B, and C.

No.	Company	Investment in Technology		Investment in Manpower		Investment in Process	
		Hardware	Software	New Hire	Training	Centralized Operation	Adaptation

						s	
1	Company A (FCC)	120,000.00	35,000.00	35,000.00	3,500.00	33,000.00	12,000.00
2	Company B (Utility Power Plant)	130,000.00	45,000.00	30,000.00	4,000.00	42,000.00	13,500.00
3	Company C (LNG Plant)	110,000.00	30,000.00	40,000.00	3,000.00	50,000.00	14,000.00

Table 11– Typical investment cost of technology, manpower, and process in order to adopting the newer assets maintenance strategy using Industrial 4.0 technology

Conclusions

Unplanned shutdown is categorized as a risk due to its randomness nature and it is difficult to predict using linearity concept of modeling. The way to minimize the occurrence of unplanned shutdown is to understand the risk and plan on the mitigation action to prevent the machinery breakdown. It is essential for an energy company to reduce the occurrence unplanned shutdown in order to improve the overall productivity.

The Industrial 4.0 technology enables the company to improve its existing assets maintenance strategy. The business solutions in this journal describe the method that can be used to identify the risks and plan for the prevention actions. The cost of the adoption of the new strategy using the Industrial 4.0 technology also mentioned in terms of return of investment, this will help the business leader of the company to justify the technology, manpower, and process change management implementation.

Using the figures from table 11, the ROI can be retrieved by dividing the Annual Saving or Translated Risk Cost Reduction (ASTR) with the total cost of investment. ROI then is translated into percentage value of the possible business risk reduction.

No.	Company	Annual Saving or Translated Risk Cost Reduction	Total Cost of Investment	ROI Translated into Possible Business Risk Reduction
1	Company A (FCC)	1,096,400.00	238,500.00	460%
2	Company B (Utility Power Plant)	1,871,064.84	264,500.00	707%
3	Company C (LNG Plant)	1,908,583.80	247,000.00	773%

Table 12 – ROI calculation of Annual Savings or Translated Risk Cost Reduction over the Industrial 4.0 technology investment cost

The Table 12 return of investment can be used to justify the investment of the new Industrial 4.0 technology to adopt the improved asset maintenance strategy.

Due to limitation of company spending budget, the investment can be also performed in multiyear phase. As such, the development of the technology should come first, followed with the concurrent development of people and process. However, only technology development will have less effective outcomes without proper manpower who are able to deliver the management of change process.

Corrective plan is a part of strategy to design an approach that targeting the severity level, occurrence index, and detection index of an asset in order to lower the level of risk. This can be reflected by improved RPN index which should be lower compare with the original ones. Improvement factor can also reflect to be a factor of potential cost reduction due to the risk.

No.	Company	Original RPN (Average)	Improved RPN (Average)	Improvement Factor	Potential Cost of Risk Reduction
1	Company A (FCC)	1.42	1.25	0.88	12.00%
2	Company B (Utility Power Plant)	1.36	1.08	0.80	20.38%
3	Company C (LNG Plant)	1.19	1.02	0.86	13.86%

Table 13 – Potential cost of risk reduction using the improvement factor calculation

The proposed technology, process, and people transformation should be aligned with the business solution that address the root cause of the risk. The company can perform the risk assessment of the cause of every shutdown, any try to mitigate by improving the effectiveness of its maintenance practice. Developing the centralized data lake to enable the establishment of expert system and analytics engine will expedite the analysis and decision-making time which lead to the improvement of the risk mitigation. Continuing from the decision-making platform through expert system advisory, the company can perform business evaluation which encompasses of internal capability assessment, assets improved RPN, and calculating the ROI on each improved condition monitoring strategy.

References

- (1) A.T. Kearney (2011), Reaching Peak O&M Performance in Power Generation.
- (2) Baker Hughes, a GE Company (2017), The Case for Condition Monitoring.
- (3) Bloomquist, Rob, et al (2015), Optimizing Plant Assets, Orbit Magazine, GE Energy.
- (4) Coleman, Chris, et al (2017), Making Maintenance Smarter, Deloitte University Press.
- (5) F. S. Nowlan, et al. (1978), Reliability-centered Maintenance, U.S. Department of Commerce.
- (6) GE Digital (2018), The Digital Twin, Compressing time-to-value for digital industrial companies.
- (7) International Atomic Energy Agency (1986), Safety Aspects of Unplanned Shutdowns and Trips.
- (8) Khan, Shahyan (2016), Leadership in the Digital Age, Stockholm Business School
- (9) Mobley, R. Keith (2002), An Introduction to Predictive Maintenance, Elsevier Science
- (10) Rogers, David L (2016), The Digital Transformation Playbook, Columbia Business School.
- (11) T. Ayral, et al. (2007), Quantifying the ROI of an Asset Performance Management Program, Hydrocarbon Processing May 2007 issue.
- (12) U.S. Department of Energy (2010), Operations & Maintenance Best Practices (Release 3.0), Federal Energy Management Program.
- (13) U. S. Energy Information Administration (2007), Refinery Outages: Description and Potential Impact on Petroleum Product Prices.
- (14) U.S. Energy Information Administration (2018), Planned Refinery Outages in the United States.

-
- (15) Westerman George, et al. (2014), Leading Digital, Harvard Business Review Press.
- (16) <https://www.forbes.com/sites/brucerogers/2016/01/07/why-84-of-companies-fail-at-digital-transformation/#68cf3ab8397b> (accessed 15 April 2019).
- (17) <https://www.epicor.com/en-us/resource-center/articles/what-is-industry-4-0/> (accessed 15 April 2019).