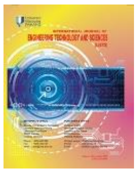
INTERNATIONAL JOURNAL OF ENGINEERING TECHNOLOGY AND SCIENCES (IJETS)
ISSN: 2289-697X (Print); ISSN: 2462-1269 (Online) Vol.6 (2) December 2019

DOI: http://dx.doi.org/10.15282/ijets.6.2.2019.1009



High-Level Performance Analysis Model for Mature Offshore Assets

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Abstract- In general, most offshore platforms are designed for 20 to 30 years of lifespan. After the field completed its maximum production plateau for a certain period, the reservoir pressure started to deplete, resulting in a decline in production rate until it is uneconomical to produce from the field. This declined production phase is referred to as Mature Offshore Fields/Assets. Almost 90% of offshore platforms in Peninsular Malaysia Assets operated by Petronas Carigali Sdn Bhd (PCSB) are within this phase. The study objective is to establish an analysis tool by consolidating the data from various system resources into a single presentation to provide the status of mature field performance, visualize the area that requires improvement, and subsequently identify performance improvement recommendations. The study will also focus on identifying which data and the resources needed to be extracted and the standards mentioned in guidelines available in the company to be used as a benchmark or comparison. This data compilation is interpreted into a Microsoft Excel spreadsheet and charts. As the study focuses on mature field operations, the three elements been identified as study subjects, i.e. plant utilization as production declining, operating cost and unplanned trips or shutdown. From the data simulation sample, the performance of Field A can be summarized and visualized clearly, and the area of improvement required can be identified with value creation being estimated.

Indexed Terms- Performance analysis, offshore, assets

I. INTRODUCTION

Most offshore platforms are generally designed for 20-30 years [1] by considering the reservoir volume to be extracted, facilities, and well-developed concepts. These reservoirs are explored and discovered using geological assessments, geophysical methods such as seismic surveys and subsequently exploratory and appraisal drilling [2]. The phase without any production is referred to as the discovery phase. The fixed platforms structures are then installed, and the drilling campaign started. Normally, multiple wells drilled in each platform depending on the reservoir locations and volume and production started to increase in this development phase [3] until it reached the mid-life phase whereby the production profile is normally at peak as the reservoir pressure was still high. Once the production started, cash is generated to pay back for the previous investments. However, all offshore facilities are subjected to production decline as the reservoir volume is depleting over time [4]. This phase is referred to as mature operations. The operations can either be continued until reservoir volume is exhausted or redeveloped to increase production and prolong the production profile. The study area will be focusing on specific to this mature operation phase.

More challenges are encountered during the mature phase as the cash generation declines due to production rate decline. At the same time, the operating cost still maintains, if not increasing, leading to reduced profit. Meanwhile, as the mature operations phase normally occurs after a significant number of years in operation and moving towards its end of design life, the equipment started to deteriorate and incur higher maintenance costs and caused more unplanned shutdowns. The facilities still need to be maintained according to the prescribed maintenance plan even though the duty services are far less than the design capacity. These challenges often call for stakeholders to devise a strategy to improve business economics by identifying measures such as minimising the unit production cost, process optimization and simplification, production enhancement, or any combinations of the proposals.

This study will specifically focus on Peninsular Malaysia Assets, whereby around 90% of the assets within the area are in the mature operations phase. The discussed issues are relevant to these assets, even though the assessment is carried out independently with varied approaches and some are not quantitatively measured [5]. Some initiatives were also carried out that were proven successful at specific platforms but not replicated or assessed at other platforms that potentially have the same issue.

This study aims to develop a standardized analysis tool for mature operations to indicate field performance, identify the performance gap, recommend the action plan and sample the tool using data from selected Field A at Peninsular Malaysia Asset. In current practice at PETRONAS Carigali Sdn Bhd, the most relevant and structured performance analysis specifically addressing the ageing offshore platforms is normally conducted through Asset Life Extension Study (ALES). ALES intends to understand the condition of these platforms in detail and provide recommendations that usually involve major upgrade and improvements to ensure the platforms can operate beyond the design life. However, this ALES study is very extensive and detailed, quite costly (ranging around MYR200,000 - MYR300,000) and relatively time-consuming (ranging from 8 months to 16 months) as referred to the previous record of ALES study for few fields in Peninsular Malaysia Assets operations. It is conducted by technical experts or consultants, once-off towards the end of the mature operations phase. While ALES is critically important to address the ageing assets, there is a need to have a simpler, high-level assessment that can be done and updated periodically to assist the stakeholders in having indicative operations performance and in establishing the focus for the area of improvements before investing cost and manhours to conduct the detailed engineering. In summary, the parameters to be assessed are overall unit production cost consisting of operations, maintenance, logistics costs, and equipment redundancy philosophy for specific processing systems, namely separation, crude export, and compression systems. On top of that, the production rate and deferment due to unplanned trips will also be quantified. All the calculation is done in MYR currency with assumptions on foreign exchange rates, inflation rate, and Brent crude price in USD currency, production rate (in kilo barrels oil per day, kbpd for crude and mmscf per day for gas).

II. METHODOLOGY

This project aims to assess the mature offshore operations performance to be able to identify the area of focus for further improvement. As the performance assessment can cover a wide range of points of view, e.g. change in operation philosophy, design duties, corrosion management etc., it is important first to specify the boundary of the assessment and subjects to be focused on [4]. The assumptions to be used throughout the project will need to be identified and defined. These will derive the extent of work, data to be collected, and the desired visualization in the result. The study scope is limited to Peninsular Malaysia Assets offshore platforms type, which is manned Complex Processing Plant and unmanned remote platforms with general processing systems such as separation, crude export and compression systems. The boundary and scopes of the study as shown in Table 1.

As depicted in Figure 1, the first step was completed by defining the three elements to be studied. The plant utilization as a result of decreasing production rate, operation cost analysis and unplanned trips study. The analysis tool developed is aimed to study those subjects and are sampled using Field A's operational days as a case study to demonstrate the data visualization, gap analysis and proposal for improvement that can be generated using this tool.

Table 1: Boundary and Scope of Study

No	Items	The boundary of the Study
1	Field location	Field A, Peninsular Malaysia Assets
2	Type of facilities	Manned Complex Processing Plant (CPP) and Unmanned remote platforms
3	Subject and Parameters to be assessed	Unit Production Cost (UPC)- MYR/barrel OPEX for logistics, operation, maintenance (MYR) Production Manifold system performance (pressure, psi) Separation Trains (flowrate kilo barrels oil per day, kbpd for crude and mmscf per day for gas) Compression System (flowrate mmscf per day)
4	Assumptions	Brent Crude Oil Price and USD Foreign Exchange rate is assumed using PETRONAS KPBI Subsurface study is excluded
5	Software or Tools to be used	Microsoft Excel

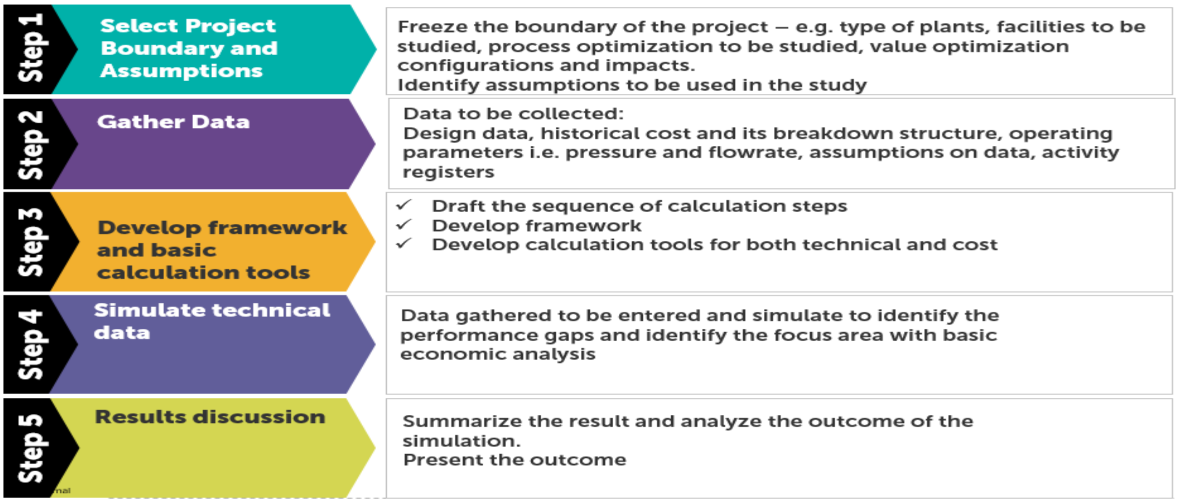


Figure 1: Project Methodology

2.1 Development of the framework for Analysis Tool

The framework of the analysis tool is developed to understand the type of data required and its resources, either from guidelines or specific reports as shown in Figure 2. For the first element to study the impact of production decline on plant utilization, the data required is the number of equipment available for each system, i.e. separation system, crude export, and gas compression systems. This information can be summarized from the Process Flow Diagram and Operation Philosophy (PCSB ORSA, 2019) accordingly [5]. The design capacity for each equipment is extracted from Equipment Dossiers, and for each system, there is an equipment redundancy philosophy applied

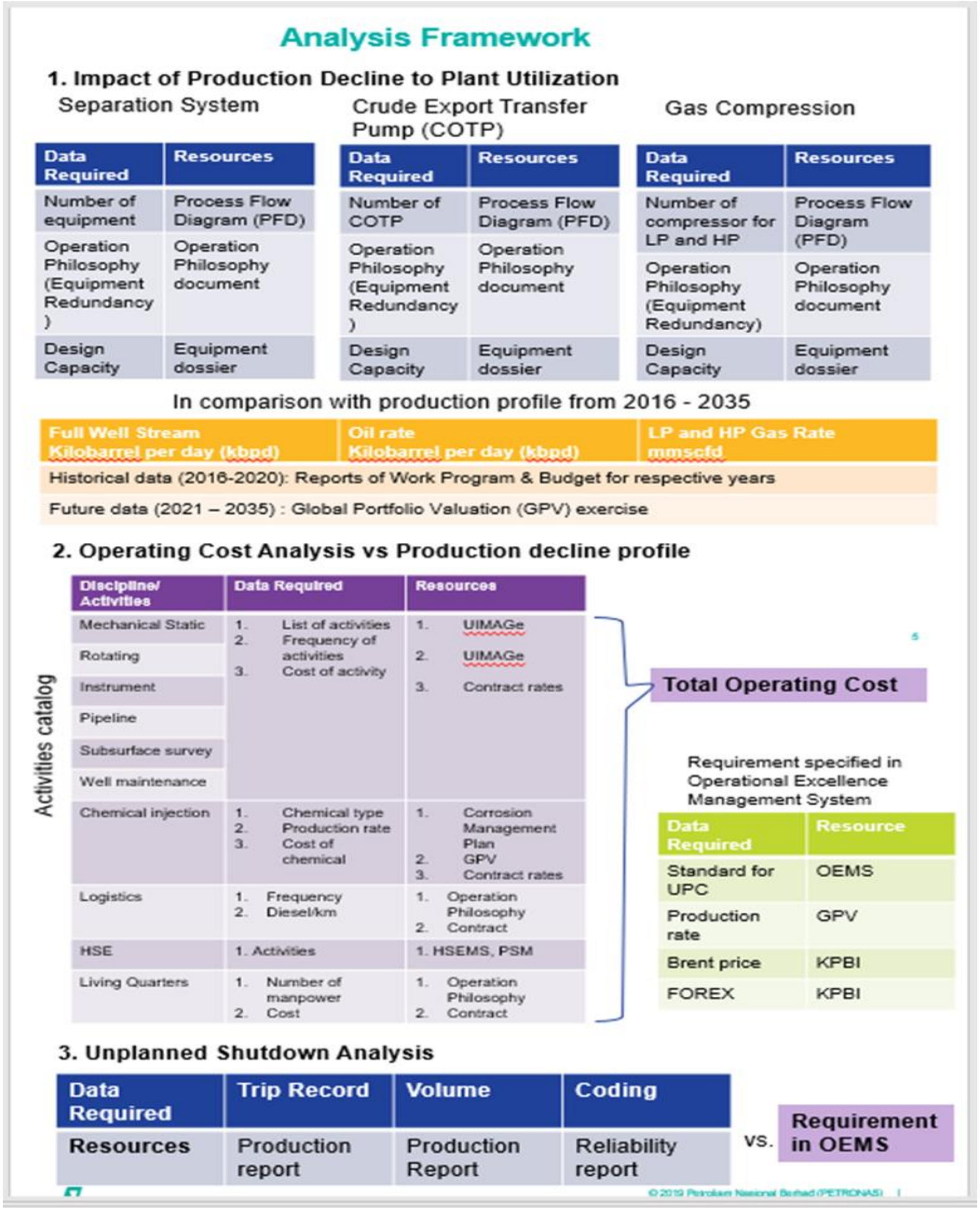


Figure 1: Analysis Framework and Data Resources

The design capacity data is then compared with production profile or throughput to understand the percentage of plant utilization and the estimated year that the process can be simplified by removing some equipment. The production profile data to be used for each system are different, such as for separation system, Full-Well-Stream (FWS) profile consolidated from each well is required, whereas, for crude transfer pump system, the export profile (kbpd) is gathered. Meanwhile, for the gas system, it is important to have a detailed profile for each Low Pressure (LP) gas and High Pressure (HP) gas profile. Historical actual production and future forecasts are separate systems or reports, but both are equally important to understand the trend better. For the second element, the operation cost is generated by using activity planning as a basis. By understanding the cost breakdown, it is easier to identify which area requires improvement and which activities can be optimized to improve the expenditure. The overall cost is compared to the target set in OEMS (cite literature), i.e. the Unit Production Cost (MYR/bbl) to be kept within 30% of the Brent crude price. Using the standard specified, the data required is the sale production profile, Brent crude price and foreign exchange rate. This comparison will demonstrate that the field will start to operate outside of the OEMS required to benchmark the estimated year. The third element, the unplanned shutdown, is analyzed as most mature field deals with ageing equipment tend to break down frequently. From the interview of several personnel in the Production and Reliability team, every unplanned shutdown shall be recorded and categorized into five main categories based on the SPO-12 Coding Guideline, namely due to Process, Wells, Rotating Equipment, External and Others factors. The unplanned shutdown data (actual deferment volume and target volume limit) is extracted from Production Report and matched with the coding report or the root cause in the Reliability report to be visualized into a pie chart. The most contributor to unplanned shutdown can be identified, and necessary improvement can be planned. It is also compared to the standard specified in OEMS for acceptable deferment volume and bad actor identification. After the framework is established on the data required and the data resources, the analysis tool is developed using Microsoft Excel based on the framework. In this study, to simulate the data, Field A was chosen as a case study. Hence, all data relevant to Field A is gathered and then entered into the analysis tool to provide performance, gaps, recommended proposals, and economic analysis for the analysis proposed options. This will give the decision-makers a high-level view on the area of concern and assisting them in deciding the deployment of the resources to carry out further detailed study and/or engineering.

III. RESULTS AND DISCUSSION

The analysis tool template was developed to assess the performance for any field with the same basic processing system. For result discussion purposes, the analysis tool was modelled using Field A's operational data. The result of the data simulation is summarized into three different sections and charts to address the three subjects under study. For each section, the tool provides analysis interpretation on the gap or focus area and provides recommendations for the next action plan.

3.1 Plant Utilization due to Production Decline

The first element is plant throughput as compared to plant design, visualized in Capacity Limit Chart below. The operation philosophy for equipment redundancy is visualized via the stacked column, i.e. COTP operating philosophy is 3x50%, Gas Scrubbers philosophy is 2x50%, LP compressor is 4x50%, and HP compressor is 2x50%. Figure 3 shows that the production profile is decreasing over time, and the throughput is mostly less than 50% of the design capacity.

Referring to Figure 4 and 5, few gaps and possible value optimizations are identified. The first gap identified is the COTP system. With current production in 2020 and future outlook, the production rate can fit into only one COTP; hence the operation philosophy can be considered to change from 3x50% to 2x100%. By changing the philosophy, one unit of the COTP can be removed or mothballed and operating, and maintenance costs will be reduced by an estimated MYR200,000 yearly. The cost reduction data is estimated using the second element of the tool, i.e. operating cost analysis. Also, it is observed from the chart that starting 2022, the production forecast is estimated to fit into only one unit of LP compressor train. This enables the operating philosophy to change from 4 x 50% to 2x 100%. The two units of Booster compressors (serving LP compression system) can be removed or mothballed to reduce the cost further, estimated at MYR350,000 per year. Also, the LP Gas Scrubber can be accommodated by only one unit instead of two, and permanently shut down the other unit of scrubber together with its two units of condensate pump can reduce the operating cost by MYR150,000 yearly. It can be summarized from this analysis that management can deploy manpower and resources to study this recommendation further by conducting flow assurance, adequacy check and relevant engineering study to ensure the initiatives can be implemented. Also, at the time this analysis is carried out, ALES for Field A is yet to be scheduled, hence showing that the process simplification and cost optimization can be identified earlier and result in better value optimization

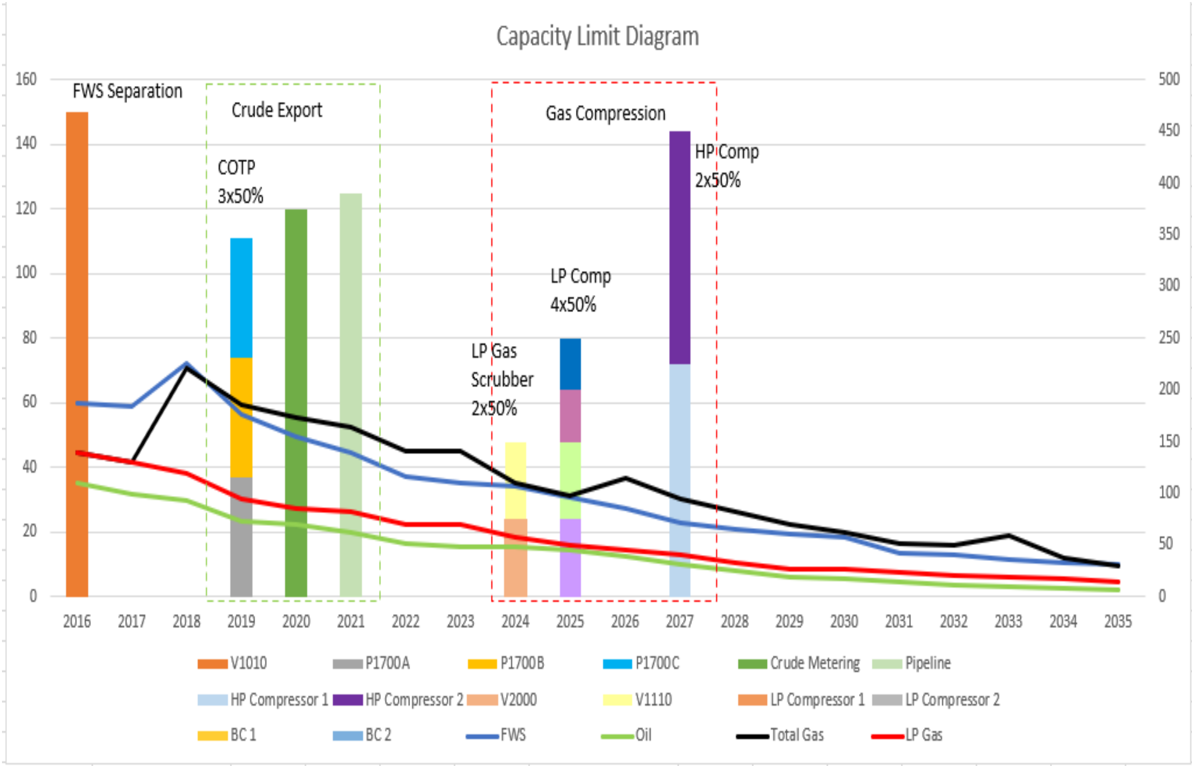


Figure 3: Plant Utilization resulted from Production decline

Summary of Production Profile

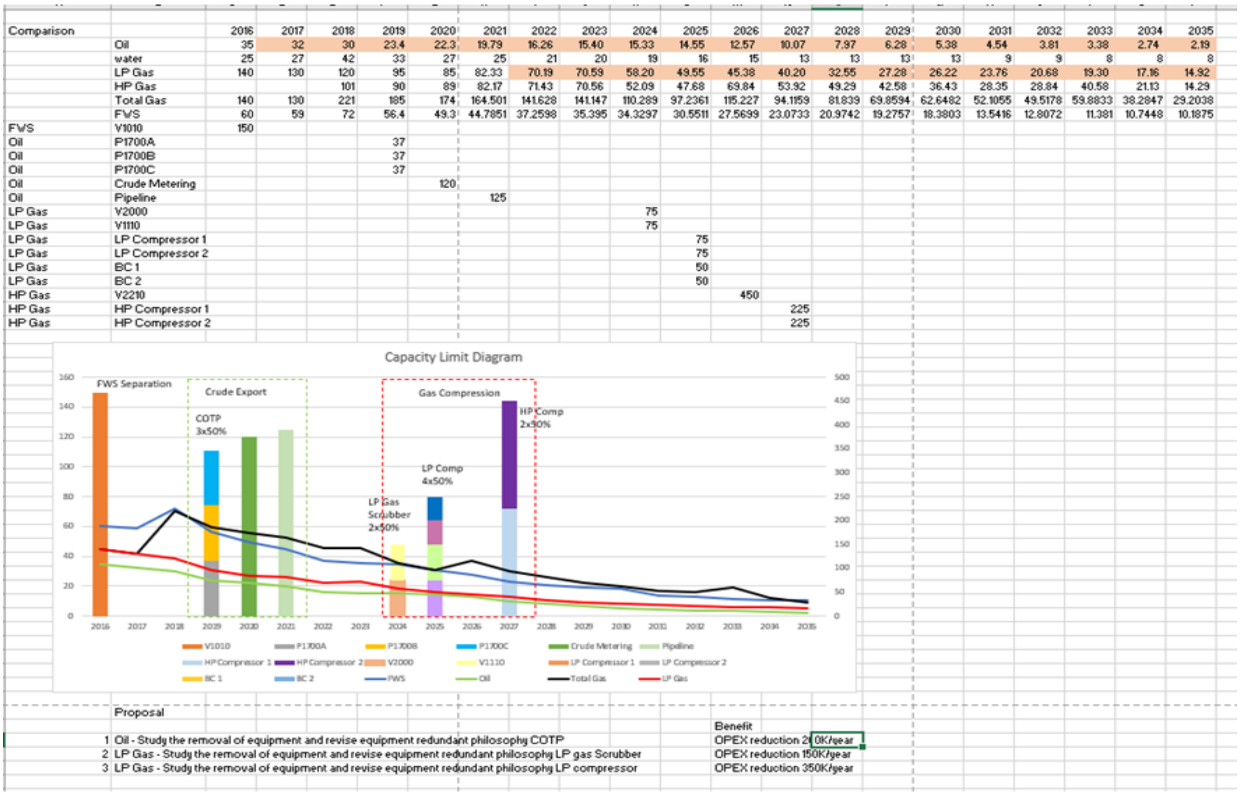
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Oil Availability (kbd) Existing						14.83	11.26	9.69	8.19	6.62	5.65	4.88	4.17	3.5
Oil Availability (kbd) Prod Enhancement						0.54	1.14	2.05	1.67	1.12	0.80	0.56	0.36	0.2
Oil Availbility (kbd) Project						-	-	-						
Gas Sales (mmscfd) Existing						156.62	130.50	121.33	96.57	83.48	71.81	58.19	45.43	34.6
Gas Sales (mmscfd) Production Enhancement						7.88	11.13	19.82	13.72	13.76	43.42	35.93	36.41	35.2
Gas Sales (mmscfd) Project						-	-	-	5.59	33.56	25.73	19.63	12.66	8.8
Gas Sales (kboed) Existing						26.10	21.75	20.22	16.10	13.91	11.97	9.70	7.57	5.7
Gas Sales (kboed) Production Enhancement						1.31	1.86	3.30	2.29	2.29	7.24	5.99	6.07	5.8
Gas Sales (kboed) Project						-	-	-						
Condensate (kbd) Existing						4.27	3.71	3.54	2.87	2.56	2.16	1.82	1.52	1.2
Condensate (kbd) Production Enhancement						0.14	0.15	0.11	0.06	0.07	0.90	0.74	0.64	0.4
Condesate (kbd) Project						-	-	-	0.10	0.87	0.63	0.43	0.28	0.2
Total Field Production (kboed)	**51.30**	**50.10**	**58.20**	**55.60**	**50.10**	**47.20**	**39.86**	**38.92**	**31.27**	**27.45**	**29.35**	**24.12**	**20.61**	**17.2**

OEMS Long Term OPEX Cost Control (LTOCC Guidelines)

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
UPC (via Before Allocation OPEX) - RM/boe	18.04	24.01	19.86	24.35	22.03	26.16	28.34	26.59	34.23	46.15	49.65	54.60	51.63	62.
KPBI Brent (KPBI2019) (USD)	45.13	54.71	71.34	64.28	41.12	40.00	44.00	46.00	48.00	49.00	50.00	53.00	56.00	57.0
30% of KBPI (Top Quartile) (RM)	60.79	91.58	106.80	114.35	38.61	50.40	54.78	57.27	59.04	60.27	61.50	65.19	68.88	70.
FOREX (KPBI2019) (RM/USD)	4.49	5.58	4.99	5.93	3.13	4.20	4.15	4.15	4.10	4.10	4.10	4.10	4.10	4.1
Maximum OPEX Threshold based on OEMS (RM)	###########	###########	###########	###########	706,072,486.32	868,326,356.80	797,077,829.50	813,553,972.26	673,847,142.31	603,757,710.18	658,748,199.56	573,966,071.20	518,081,776.15	441,662,632.9

Graph of Long Term OPEX vs. Production

Figure 4: Simulation Result of Plant Utilization (Part A)



Comparison		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
	Oil	35	32	30	23.4	22.3	19.79	16.26	15.40	15.33	14.55
	water	25	27	42	33	27	25	21	20	19	16
	LP Gas	140	130	120	95	85	82.33	70.19	70.59	58.20	49.55
	HP Gas			101	90	89	82.17	71.43	70.56	52.09	47.68
	Total Gas	140	130	221	185	174	164.501	141.628	141.147	110.289	97.2361
	FWS	60	59	72	56.4	49.3	44.7851	37.2598	35.395	34.3297	30.5511
FWS	V1010	150									
Oil	P1700A				37						
Oil	P1700B				37						
Oil	P1700C				37						
Oil	Crude Metering					120					
Oil	Pipeline						125				
LP Gas	V2000									75	
LP Gas	V1110									75	
LP Gas	LP Compressor 1										75
LP Gas	LP Compressor 2										75
LP Gas	BC 1										50
LP Gas	BC 2										50
HP Gas	V2210										
HP Gas	HP Compressor 1										
HP Gas	HP Compressor 2										

Comparison		2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
	Oil	12.57	10.07	7.97	6.28	5.38	4.54	3.81	3.38	2.74	2.19
	water	15	13	13	13	13	9	9	8	8	8
	LP Gas	45.38	40.20	32.55	27.28	26.22	23.76	20.68	19.30	17.16	14.92
	HP Gas	69.84	53.92	49.29	42.58	36.43	28.35	28.84	40.58	21.13	14.29
	Total Gas	115.227	94.1159	81.839	69.8594	62.6482	52.1055	49.5178	59.8833	38.2847	29.2038
	FWS	27.5699	23.0733	20.9742	19.2757	18.3803	13.5416	12.8072	11.381	10.7448	10.1875
FWS	V1010										
Oil	P1700A										
Oil	P1700B										
Oil	P1700C										
Oil	Crude Metering										
Oil	Pipeline										
LP Gas	V2000										
LP Gas	V1110										
LP Gas	LP Compressor 1										
LP Gas	LP Compressor 2										
LP Gas	BC 1										
LP Gas	BC 2										
HP Gas	V2210	450									
HP Gas	HP Compressor 1		225								
HP Gas	HP Compressor 2		225								

	Proposal	Benefit
1	Oil - Study the removal of equipment and revise equipment redundant philosophy COTP	OPEX reduction 2(0K/year
2	LP Gas - Study the removal of equipment and revise equipment redundant philosophy LP gas Scrubber	OPEX reduction 150K/year
3	LP Gas - Study the removal of equipment and revise equipment redundant philosophy LP compressor	OPEX reduction 350K/year

Figure 5 Simulation Result of Plant Utilization (Part B)

3.2`Operation Cost Analysis

In the second section, basic operations and maintenance activities are catalogued and compiled as specified in the Upstream Inspection and Maintenance Guideline (UIMAGe), with recommended frequency and cost as per the existing contract rate. By entering information on how much equipment is available, the manpower available for the field, the mode of logistics being used, and the total yearly operating cost for Field A. Figure 6 shows the total operating cost to the limit of 30% of Brent Crude price. From this figure, it is clear that the production decreases while the operation cost maintains at around the same level. The 30% crude price limit line fluctuates due to the crude price and foreign exchange rate fluctuation itself. The PETRONAS key assumption KPBI was revised to reflect the slow increase in future estimation from the recent major drop in crude oil price. Also, this analysis, shows that Field A operating cost will reach its 30% crude price limit in 2029. By having this forecast upfront, the operation management team will have ample time to strategize the change in how the plant to be operated in future to optimize the cost.

If the chart is further focused on without visualizing the 30% crude price limit line (Figure 7), the total cost breakdown can be understood better. The majority of the cost is contributed by Surface, Maintenance and Logistics cost. With this information, the proposal for reducing the operating cost can be strategized effectively. For example, the operation team will adopt the process simplification as proposed in item 3.1 and reduce the maintenance cost. Also, the maintenance philosophy can be revised to reduce the frequency of maintenance towards the end of life. Meanwhile, the surface and logistic costs can be further reduced by reducing the manpower and the visit frequency to remote platforms.

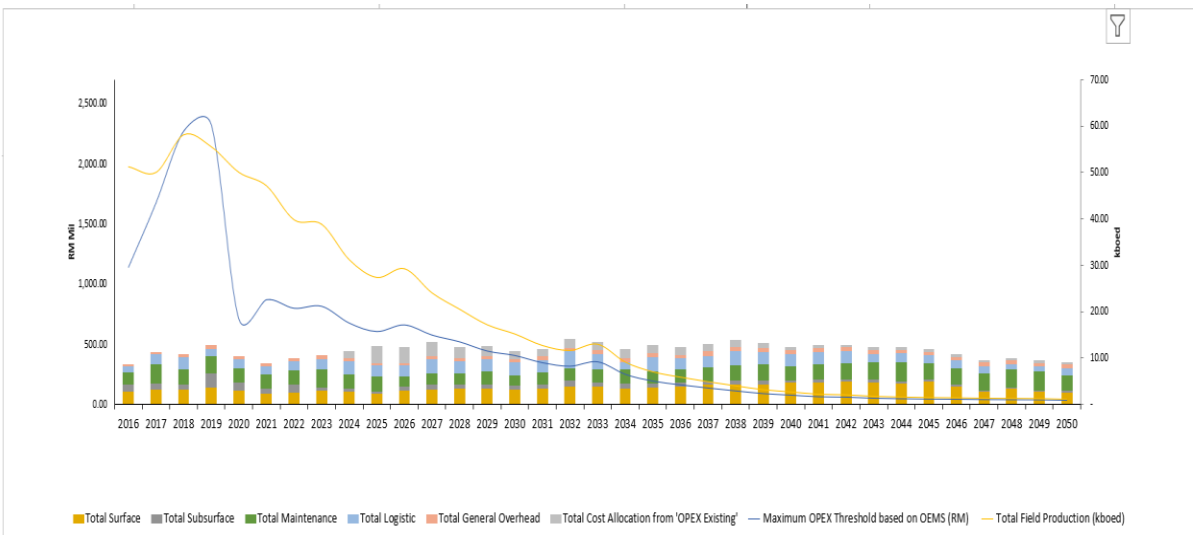


Figure 6: Total cost comparison to 30% Brent crude price limit

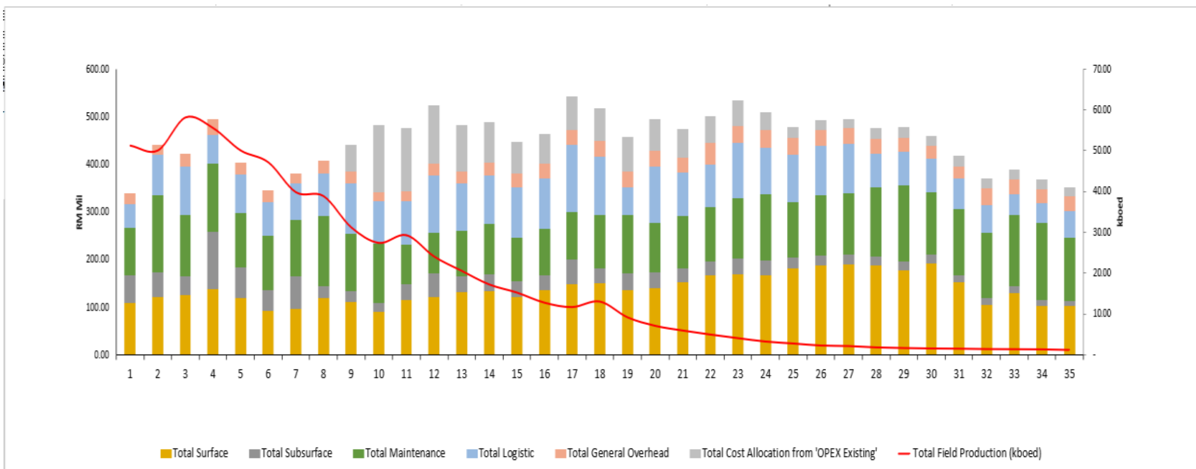


Figure 7: Total Operating Cost Breakdown

3.3 Unplanned shutdown analysis

In the third section, the analysis focuses on identifying trends in equipment integrity, and unplanned deferment as the mature offshore fields are usually aged, and frequent trips are expected. Specifically, for Field A, the platforms are almost 20 years in operation. The equipment integrity is analyzed by consolidating the unplanned plant trips record from 2016 to 2019 and filtering the root cause of the trips. As all the trips were categorized into a coding, repetitive trips due to the same root, the cause will be identified. From data compilation for unplanned trips for Field A in Figure 8, the unplanned shutdowns only contribute to 2.27% from overall plant availability, compared to the benchmark of world class operators specified in OEMS to be below 15%. From this analysis, it indicates that Field A does not address alarming issues on equipment breakdown that affecting plant availability

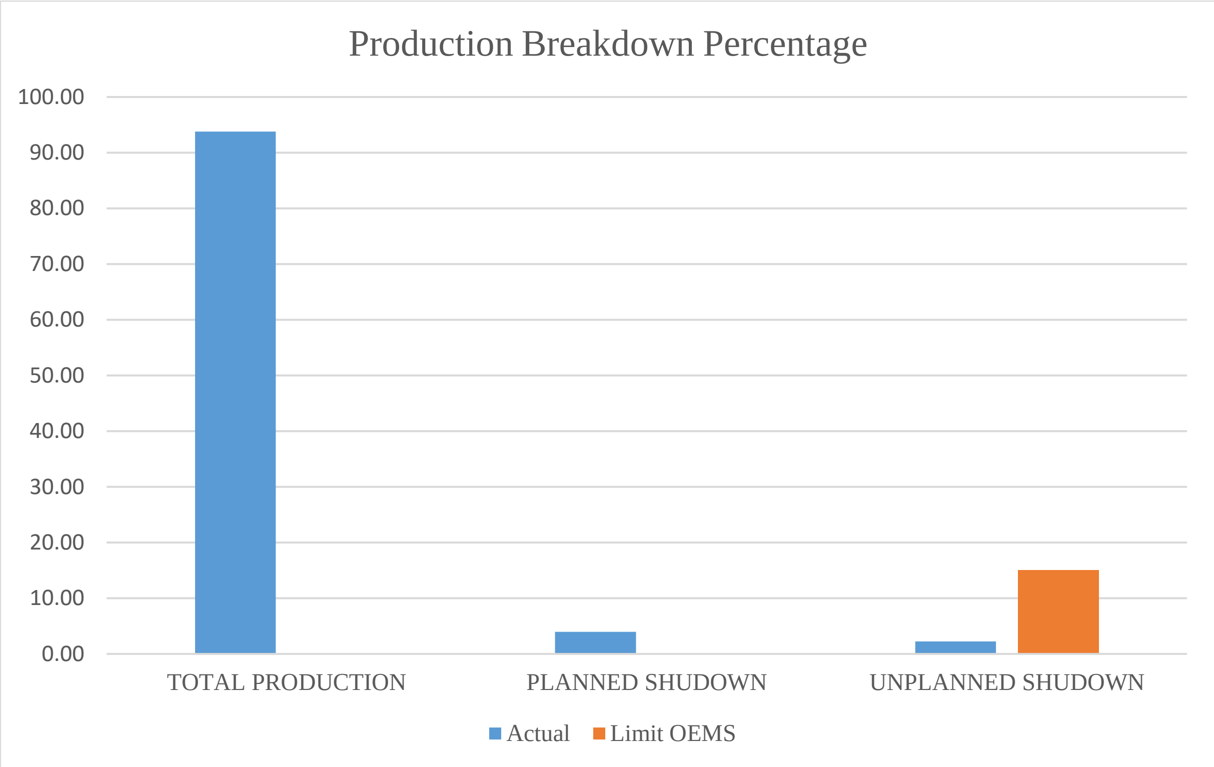


Figure 8: Unplanned Shutdown volume percentage for the duration of 2016-2019

The unplanned shutdown records are further analyzed and represented in the pie chart in Figure 9, showing that most of the unplanned deferment or trips are due to wells behavior such as low reservoir pressure, inability to flow, well control tripped, etc. The second root cause category is process control upset, such as gas lift valve stuck, leaking at process control valve, etc. Even though the causes are not repetitive for the same instrumentation equipment, it is noted that the majority of the event is due to valve maintenance. Hence, one of the proposals for improvement to be taken up is improving on valve maintenance scope and inspection. The other root cause falls within external factors, which are usually uncontrollable, such as bad weather and instruction from receiving end at offshore as part of overall gas supply network management. Rotating equipment was found to have a very minimum unplanned trip.

IV. CONCLUSION

Performance analysis is a vital aspect of having an effective operation management system. Without this, the actual performance of any business or operations would not be understood fully. In this study, few problematic areas can be identified from the analysis, and an action plan can be strategized better to address specific issues normally faced by the mature operations phase, namely declining production rate that calls for process simplification and operating cost and maintenance philosophy to be further optimized to ensure business economics. Although the analysis tool is modelled using Field A's operational data, it can be replicated for any other field with a basic processing system of separation, crude export, and gas compression. The analysis tool or template must be configured once for each field and only require data updates in subsequent years or periods. Automatic data retrieval will improve the tool tremendously as it can provide real-time analysis and reduce the resources and manhours. The analysis tool only provides indicative problems and proposals and is completed with a detailed engineering study. It also does not replace the thorough and holistic assessment of asset life study.

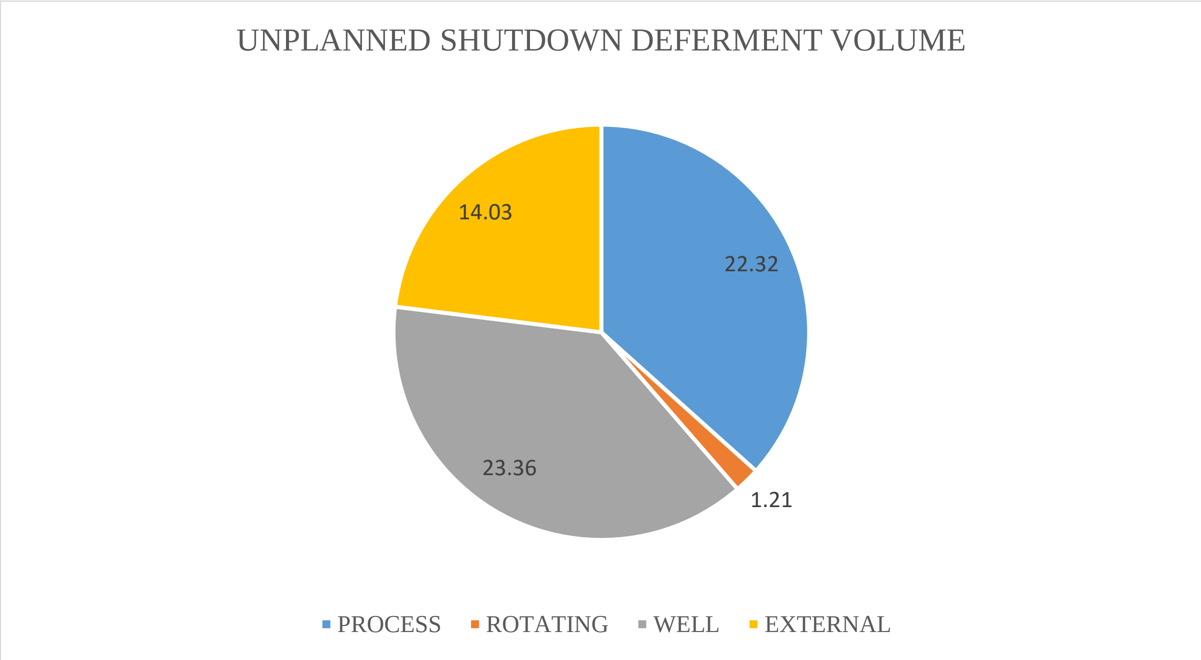


Figure 9 Unplanned shutdown root cause category analysis

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