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Evaluation of Offshore Production Performance in Mature Fields: Case Study of Foxtrot Flow Station

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ABSTRACT

This study examines offshore production performance at Foxtrot Flow Station, PT PHE ONWJ, utilizing an integrated Key Performance Indicators framework across productivity, operations, economics, and HSSE dimensions. A qualitative approach was employed, combining 2022–2025 production data analysis with cross-functional interviews. The results reveal that the system operates under system-constrained conditions driven by aging assets, gas lift imbalance, and declining maintenance effectiveness. Production performance averages 88% of targets, with deficits dominated by hidden losses—specifically tubing obstruction from inefficient gas lift injection. Operationally, the facility exhibits pseudo-reliability, where high mechanical availability fails to translate into effective production. Economically, declining volumes inflate lifting costs per barrel, though HSSE metrics remain resilient with zero recorded incidents. A reinforcing decline loop is identified, where falling production limits gas lift availability, further degrading output. These findings emphasize the necessity of integrated gas lift optimization, asset integrity management, and predictive maintenance to secure mature offshore asset resilience.

Keywords: *Asset Integrity Management, Gas Lift Optimization, Mature Oil and Gas Fields, Production Performance Evaluation.*

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1. | INTRODUCTION

Offshore oil and gas production remains a critical pillar of global energy supply despite the accelerating transition toward low-carbon systems. Hydrocarbon resources continue to support industrial activity, transportation, and national energy security, particularly in emerging economies with rising demand. Consequently, optimizing production from existing offshore assets has become increasingly important as operators face pressure to sustain output, improve efficiency, and maintain economic viability (International Energy Agency, 2020).

This challenge is particularly significant for mature offshore fields. As assets age, production sustainability becomes constrained not only by reservoir depletion but also by operational complexity, facility degradation, and increasing maintenance requirements (Economides et al., 2013). Offshore production systems are highly integrated environments in which well performance, artificial lift reliability, surface processing capability, and maintenance effectiveness interact dynamically (Jahn et al., 2008).

Marine exposure further intensifies these challenges through corrosion and structural degradation. Offshore infrastructure deterioration progressively reduces equipment reliability and operational continuity (Melchers, 2005; Melchers & Jeffrey, 2008). In gas lift-dependent systems, these effects become more critical because production performance relies heavily on stable compressor operation, balanced gas distribution, and downhole integrity. Disturbances in these components often generate substantial production inefficiencies (Brown, 1984; Takács, 2005).

A key challenge in mature offshore operations is that production losses frequently occur even when systems remain technically available. Such latent inefficiencies may arise from gas lift instability, partial equipment degradation, or process restrictions that do not trigger formal shutdown classification. This creates conditions where operational availability does not necessarily translate into effective production deliverability.

Conventional performance evaluation typically relies on isolated Key Performance Indicators (KPIs), including production achievement, downtime, equipment reliability, maintenance performance, and cost efficiency. While useful for monitoring, fragmented KPI assessment often fails to capture causal interdependencies across operational dimensions. Previous studies emphasize that effective performance measurement requires integrated and systemic evaluation frameworks capable of diagnosing root causes rather than merely reporting outcomes (Behn, 2003; Neely et al., 2005; Parmenter, 2015).

From a systems perspective, operational deterioration often emerges through reinforcing feedback loops rather than isolated failures (Sterman, 2000). In mature gas lift systems, declining compressor reliability may reduce injection efficiency, lower oil production, and decrease associated gas availability, thereby reinforcing production decline. Similarly, aging infrastructure requires maintenance strategies beyond routine preventive schedules, emphasizing reliability-centered and predictive approaches (Moubray, 1997).

Despite growing recognition of integrated performance evaluation, empirical implementation remains limited, particularly in Indonesian mature offshore assets where operational data are fragmented across production, maintenance, and loss-management systems loss-management systems, and this study addresses this gap through a qualitative case study of Foxtrot Flow Station operated by PT Pertamina Hulu Energi Offshore North West Java (PHE ONWJ). Using an integrated KPI framework, the study evaluates four interrelated dimensions: productivity, operational performance, economic performance, and HSSE.

This study contributes to the existing literature in several ways. First, it extends offshore performance evaluation by integrating multidimensional Key Performance Indicators (KPIs), enabling a more comprehensive assessment of operational effectiveness. Second, it provides empirical evidence from an underrepresented Southeast Asian offshore context, thereby enriching the limited body of research in this region. Third, the study introduces systemic concepts such as system-constrained production, hidden losses, and pseudo-reliability, highlighting situations in which nominal operational availability appears satisfactory while actual deliverability continues to decline, resulting in a gap between perceived and effective operational performance.

2. | LITERATURE REVIEW

This section reviews the theoretical and empirical foundations relevant to offshore production performance evaluation in mature fields. The review synthesizes prior studies on offshore production systems, gas lift operational constraints, integrated performance measurement, maintenance reliability, and system resilience. By critically evaluating previous empirical findings, this section establishes the conceptual basis for the integrated KPI framework employed in this study and identifies the research gaps addressed through the Foxtrot Flow Station case.

Operational performance in mature offshore fields is shaped by declining reservoir pressure, increasing water cut, unstable flow behavior, and growing dependence on artificial lift systems (Economides et al., 2013). Sustained production therefore depends not solely on reservoir potential but on the reliability of interconnected operational subsystems (Jahn et al., 2008). Gas lift is particularly sensitive to compressor reliability, injection pressure stability, and gas allocation balance (Brown, 1984; Takács, 2005). Empirical studies show that production constraints in mature assets often stem from operational inefficiencies rather than subsurface limitations. Optimization studies have demonstrated measurable production recovery through improved gas distribution and surveillance practices. A critical issue is the emergence of hidden production losses performance degradation occurring without explicit downtime events. These conditions often reflect latent operational inefficiencies that remain undetected under conventional monitoring systems.

Performance measurement literature highlights similar limitations. Effective KPI systems must capture relationships among operational variables rather than assess metrics independently (Behn, 2003; Neely et al., 2005; Parmenter, 2015). In offshore systems, production performance emerges through dynamic interaction among technical reliability, maintenance strategy, process continuity, and economic efficiency. Maintenance plays a central role in this interaction. Offshore assets are exposed to nonlinear degradation due to corrosion and marine stress (Melchers, 2005; Melchers & Jeffrey, 2008). As facilities mature, conventional preventive maintenance often becomes insufficient, requiring reliability-centered approaches emphasizing condition monitoring and predictive intervention (Moubray, 1997). When tracking these technical degradation patterns over time, evaluating separate components independently fails to capture how operational failures cascade across the facility.

From a systems-thinking perspective, mature offshore decline reflects reinforcing feedback mechanisms linking technical degradation, operational instability, and managerial response (Sterman, 2000). These dynamics position operational resilience as a function of integrated system capability rather than isolated technical performance. While this systemic perspective highlights the deeply interconnected nature of late-life operations, existing literature has not fully translated these foundational insights into actionable, unified evaluation models.

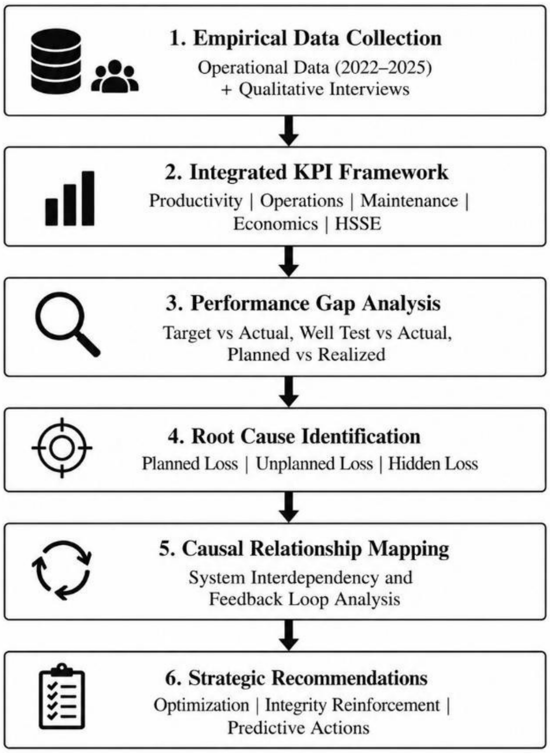
The literature demonstrates substantial advances in offshore production optimization, gas lift engineering, maintenance reliability, and performance measurement systems. However, three important gaps remain. First, most prior studies evaluate mature-field performance through isolated technical perspectives such as reservoir decline, compressor performance, or maintenance reliability, with limited multidimensional integration. Second, latent operational degradation mechanisms particularly hidden production losses occurring under nominal system availability remain insufficiently explored. Third, empirical studies linking integrated KPI evaluation with system integration, sustainability, and corporate resilience in mature offshore production systems remain scarce, particularly in Southeast Asian offshore operational contexts. This study addresses these gaps through an integrated qualitative case analysis of Foxtrot Flow Station, providing empirical evidence on how multidimensional operational constraints shape production sustainability in mature offshore assets.

3. | RESEARCH METHOD

This study applies a qualitative case study methodology to evaluate offshore production performance in a mature oil and gas asset environment. The methodological approach was developed to capture the multidimensional and interdependent nature of offshore production systems, where operational performance is influenced by interactions among technical reliability, maintenance effectiveness, production continuity, economic efficiency, and operational safety. The analytical process integrates longitudinal operational data and qualitative evidence through an Integrated Key Performance Indicator (KPI) framework. The methodological workflow consists of sequential analytical stages: empirical data consolidation, multidimensional KPI evaluation, performance gap analysis, root cause identification, causal relationship mapping, and strategic recommendation development. This structured approach enables the study to move beyond descriptive performance measurement toward systemic diagnosis of production constraints and operational resilience assessment.

To operationalize this diagnostic approach, a robust conceptual design was established to bridge multi-source datasets with systemic analysis tools. This study employed a qualitative case study design to evaluate offshore production performance at Foxtrot Flow Station, operated by PT Pertamina Hulu Energi Offshore North West Java (PHE ONWJ), Indonesia. The case study approach was selected because mature offshore production performance emerges from complex interactions among technical, operational, and organizational factors that cannot be adequately captured through isolated quantitative analysis (Yin, 2018). Operational data and qualitative evidence were integrated through an Integrated KPI framework. The analytical workflow consisted of data consolidation, KPI evaluation, performance gap analysis, root-cause identification, causal relationship mapping, and strategic recommendation development. The analytical framework integrates longitudinal operational records and qualitative interview evidence across five KPI dimensions examined, namely Productivity, Operational Performance, Maintenance Performance, Economic Performance and HSSE. Analysis followed sequential stages of data consolidation, KPI gap assessment, thematic coding, causal relationship mapping, and strategic interpretation.

Figure 1. illustrates the analytical flow of the study, beginning with empirical data acquisition and proceeding through sequential diagnostic stages toward strategic recommendation development. The framework enables multidimensional evaluation of offshore production performance while capturing systemic interactions that may not be visible through isolated KPI assessment. Applying this integrated framework requires a detailed understanding of the specific operational ecosystem where these metrics and technical interactions manifest. This study was conducted at Foxtrot Flow Station, an offshore oil and gas production facility operated by PT Pertamina Hulu Energi Offshore North West Java in the Offshore North West Java working area, Indonesia. Foxtrot Flow Station represents a mature offshore production asset characterized by declining reservoir performance, aging surface facilities, and increasing operational complexity associated with long-term production sustainability.



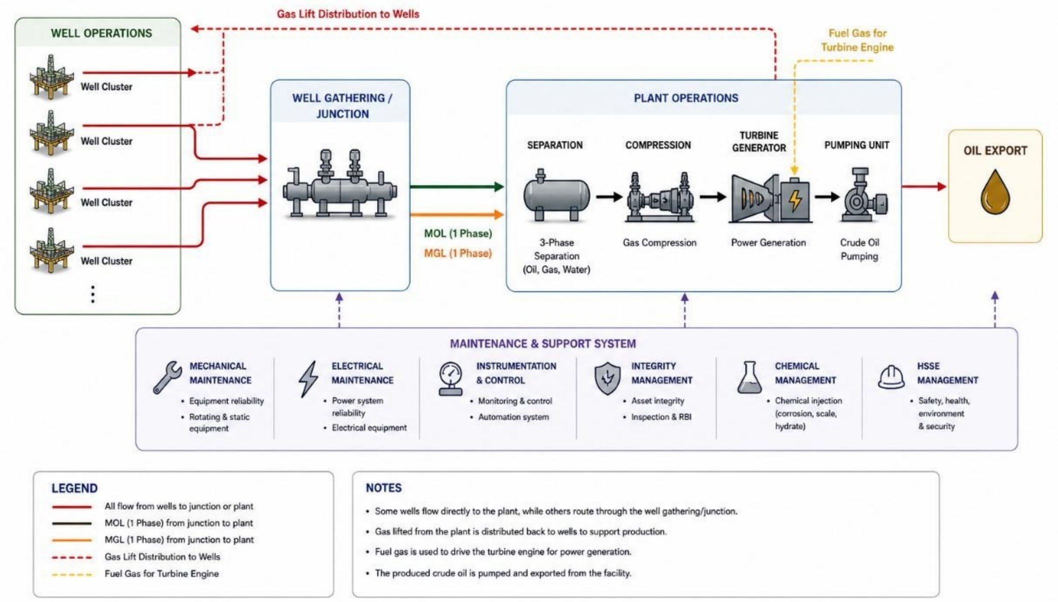
Source: Developed by the author based on Neely et al. (2005); Sterman (2000), and the integrated KPI framework adopted in this study.

Figure 1. Conceptual framework for integrated offshore production performance evaluation.

The production system operates as an integrated offshore processing network consisting of three primary operational domains: well operations, plant operations, and maintenance-support systems. Well operations involve multiple offshore well clusters producing hydrocarbons through gas lift-assisted artificial lift mechanisms. Produced fluids are transported either directly to the central processing facility or routed through well gathering and junction systems prior to entering the processing plant. Plant operations function as the central processing hub of the production system, where multiphase fluids undergo separation, gas compression, power generation support, and crude oil pumping prior to export. The gas handling subsystem performs a dual operational role: supporting gas lift redistribution to production wells and supplying fuel gas for turbine engine operation. This configuration creates a high level of operational interdependency between production continuity, gas lift availability, and facility processing reliability.

Supporting these core operational functions is an integrated maintenance and technical support system comprising mechanical maintenance, electrical maintenance, instrumentation and control, chemical injection management, integrity monitoring, and HSSE oversight. The effectiveness of these supporting functions directly influences equipment reliability, production stability, and operational resilience. Foxtrot Flow Station was selected as the empirical setting of this study because it exhibits representative characteristics of mature offshore production assets, including production decline, dependence on artificial lift optimization, integrity-related operational constraints, and increasing maintenance requirements. These characteristics make the facility an appropriate case for evaluating multidimensional production performance using an integrated KPI-based analytical framework.

The operational configuration of Foxtrot Flow Station is illustrated in Figure 2 presents the general operational architecture of Foxtrot Flow Station. Hydrocarbon production originates from distributed well clusters and is transported through flowline systems toward either well gathering junctions or directly to the processing facility. The plant processing system separates produced fluids, manages gas compression, supports turbine-based power generation, and pumps crude oil for export. Simultaneously, processed gas is redistributed for gas lift injection and turbine fuel supply, creating a tightly coupled production-support loop. This integrated configuration makes system-wide operational performance highly sensitive to disruptions occurring at any point within the production chain.



Source: Developed by the author based on Foxtrot Flow Station operational process documentation and field operational interviews (2025).

Figure 2. Simplified operational system of Foxtrot Flow Station

Because this physical network is deeply tightly coupled, investigating its systemic constraints required deep contextual insights from the personnel managing these day-to-day interactions. This study employed purposive sampling to select participants with direct operational involvement and technical decision-making responsibilities relevant to production performance at Foxtrot Flow Station. Purposive sampling is widely applied in qualitative case study research when participants are selected based on their knowledge, experience, and relevance to the phenomenon under investigation rather than statistical representativeness (Yin, 2018; Creswell & Poth, 2018). The sampling strategy was designed to ensure cross-functional representation across the primary operational domains influencing offshore production performance. Given that production outcomes in mature offshore assets emerge from interdependencies among technical reliability, operational continuity, maintenance execution, and safety performance, participant selection prioritized personnel directly involved in operational execution, system monitoring, and performance decision-making.

A total of 30 core participants were included in the study. The participant group consisted of two operational superintendents representing strategic management oversight; five well operation personnel, comprising one supervisor and four well operators; and five plant operation personnel, consisting of one supervisor and four plant operators. The maintenance function was represented by twelve participants, including one maintenance supervisor, two mechanical technicians, two electrical technicians, two instrumentation technicians, and five deck operation support personnel. The HSSE function involved two participants, comprising one HSSE officer and one medic doctor. Four additional technical support personnel participated in the study, including one turbine condition monitoring technician, one chemical injection technician, one corrosion monitoring technician, and one offshore operations assistant. The participant distribution is summarized in Table 1.

Table 1. Core participant distribution

Functional Area	Participants	Experience (year)	Primary Analytical Contribution
Operational Management	2	18-22	Strategic operational evaluation
Well Operations	5	9-20	Production surveillance and gas lift performance
Plant Operations	5	9-21	Process continuity and facility operations
Maintenance	12	5-22	Reliability, integrity, and maintenance effectiveness
HSSE	2	10-15	Safety and environmental performance
Technical Support	4	10-18	Condition monitoring and supporting technical systems
Total	30	-	Integrated production system assessment

The participant composition ensured analytical coverage across all dimensions of the integrated KPI framework. Including respondents from multiple organizational levels enabled triangulation between strategic-level operational interpretation and field-level execution realities. Data collection continued until thematic saturation was achieved, indicated by recurring explanations of production constraints, maintenance challenges, and operational interdependencies across participant groups, with no substantively new analytical insights emerging in subsequent interviews (Guest et al., 2006). This cross-functional sampling structure strengthens the credibility of the qualitative findings by reflecting the systemic nature of offshore production performance in mature asset environments. To build upon these cross-functional insights, the qualitative narratives were systematically paired with hard operational data streams generated directly by the asset. This study employed multiple quantitative and qualitative data sources to ensure analytical depth and methodological triangulation. Operational records were integrated with interview-based insights to capture measurable performance trends alongside contextual operational interpretation. Table 2 summarizes the data collection structure used in this study.

Table 2. Data Collection Structure

Data Source	**Type**	**Coverage**	**Analytical Purpose**
Operational production records	Quantitative operational data	2022–2025	Trend and performance gap analysis
Production loss reports (PLMS)	Quantitative operational data	2022–2025	Loss categorization and root cause identification
Maintenance records	Quantitative operational data	2022–2025	Reliability and maintenance effectiveness analysis
Shutdown logs	Quantitative operational data	2022–2025	Operational disruption assessment
HSSE reports	Quantitative operational data	2022–2025	Safety performance evaluation
*Semi-structured interviews	Qualitative data	30 participants	Operational interpretation and contextual validation

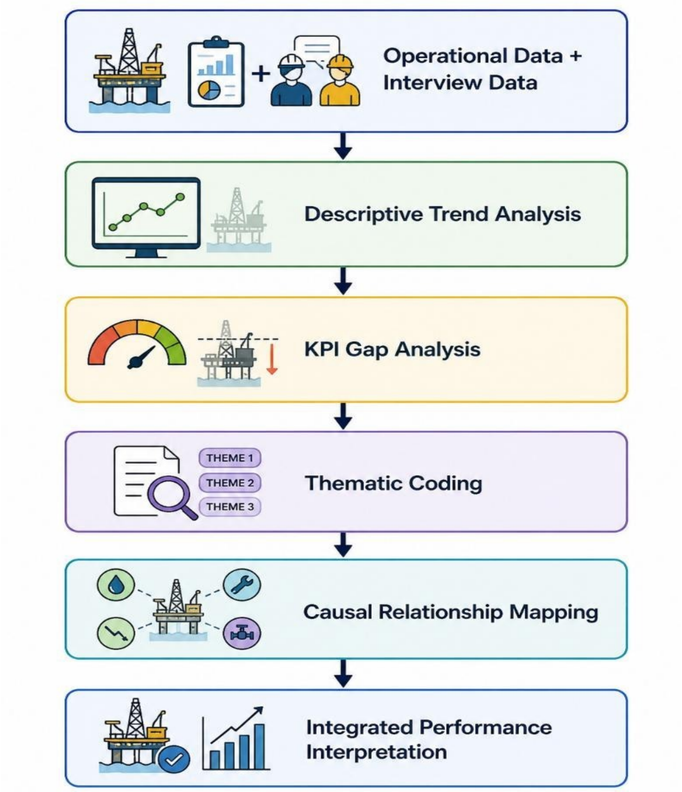
The collected operational and qualitative datasets were analytically translated into five integrated KPI dimensions to provide a structured basis for performance evaluation. This operationalization framework ensured alignment between observed operational evidence and analytical interpretation. Table 3 presents the KPI operationalization framework employed in this study.

Table 3. Integrated KPI Operationalization Framework

KPI Dimension	Key Indicators	Data Source	Analytical Objective
Productivity	Production rate, target achievement, well test gap, loss production	Daily production reports, PLMS	Evaluate production effectiveness
Operations	Shutdown frequency, facility availability, process interruptions	Shutdown logs, operational reports	Assess operational continuity
Maintenance	Planned vs unplanned maintenance, equipment failure trends	Maintenance records	Evaluate reliability effectiveness
Economics	Lifting cost, budget allocation efficiency	Cost performance reports	Assess economic sustainability
HSSE	NLTI, safe man-hours, incident frequency, safety observations	HSSE documentation	Evaluate operational safety resilience

The framework enabled systematic interpretation of operational performance by linking measurable indicators with their corresponding managerial evaluation objectives. This structure also supported analytical triangulation between quantitative operational evidence and qualitative contextual interpretation derived from interview data.

Data analysis followed four stages. First, descriptive trend analysis identified longitudinal performance patterns. Second, KPI gap analysis compared planned versus realized performance. Third, interview data were coded thematically using an inductive-deductive approach (Braun & Clarke, 2006), producing themes such as hidden production losses, pseudo-reliability, gas lift imbalance, and asset degradation. Fourth, causal relationship mapping synthesized operational and interview evidence to identify reinforcing degradation loops. The analytical workflow is summarized in Figure 3.



Source: Developed by the author based on (Miles et al., 2014), integrated with the analytical procedure employed in this study.

Figure 3. Data analysis workflow

This multi-stage analytical approach enabled comprehensive evaluation of production performance by integrating quantitative operational evidence with qualitative operational interpretation. Such integration is particularly appropriate for mature offshore production systems where performance degradation often emerges through interacting technical and operational mechanisms rather than single-factor failures (Miles et al., 2014).

To strengthen methodological rigor, this study employed multiple strategies to ensure credibility, dependability, and analytical trustworthiness. First, data triangulation was applied through the integration of multiple operational evidence sources, including production performance records, production loss reports, maintenance records, shutdown logs, HSSE documentation, and semi-structured interview data.

Triangulation enabled cross-validation between recorded operational outcomes and participant interpretations, reducing dependence on any single source of evidence (Patton, 2015). Second, cross-functional respondent triangulation was implemented by including participants from operational management, well operations, plant operations, maintenance, HSSE, and technical support functions. This approach allowed comparison of perspectives across hierarchical and functional boundaries, strengthening analytical consistency. Third, thematic saturation guided interview completion. Data collection continued until recurring explanations of production constraints, operational disruptions, and system interdependencies emerged consistently across participant groups, with no substantively new analytical themes identified in later interviews (Guest et al., 2006).

Fourth, documentary verification was used to confirm interview interpretations against objective operational records. Where participant narratives indicated specific operational constraints, these interpretations were cross-checked against documented performance trends and production loss records. Finally, analytical reliability was strengthened through systematic coding procedures and iterative analytical review. Emerging themes were repeatedly evaluated against raw interview notes and operational datasets to ensure internal consistency and analytical coherence. These procedures collectively enhance the trustworthiness of the findings and support robust interpretation of offshore production performance dynamics within Foxtrot Flow Station.

4. | RESULTS

This section presents the empirical findings derived from longitudinal operational performance records and qualitative interview data collected at Foxtrot Flow Station. Consistent with the integrated Key Performance Indicator (KPI) framework developed in this study, the findings are organized into five analytical dimensions: productivity, operational performance, maintenance effectiveness, economic performance, and health, safety, security, and environment (HSSE). The results are presented through descriptive trend analysis, KPI gap assessment, and thematic operational evidence identified from cross-functional participant responses. The presentation emphasizes observable performance patterns, operational deviations, and recurring system constraints identified during the study period. The findings are reported sequentially according to the analytical workflow established in the methodological framework, beginning with productivity performance as the primary operational outcome. An integrated synthesis of cross-dimensional findings is presented at the end of this section to summarize dominant operational patterns observed across Foxtrot Flow Station.

To establish the primary baseline of operational outcomes, productivity metrics were tracked longitudinally to contrast intended planning targets against field production realities. Productivity performance was assessed through longitudinal evaluation of annual production achievement, monthly production realization gaps, well test conversion performance, and production loss distribution during the 2022–2025 observation period. The analysis identifies observable production trends and deviations between planned production targets, tested well capability, and realized operational output under mature field operating conditions. The annual production performance trend is presented in Table 4.

Table 4. Longitudinal productivity performance of Foxtrot Flow Station (2022–2025)

Year	Base Fluid (bfpd)	Actual Fluid (bfpd)	Fluid Perform (%)	Base Oil	Actual Oil	Oil Perform (%)	Loss oil (bfpd)	Loss oil (bfpd)	Fluid Decline (%)	Oil Decline (%)
2022	30.782	27.695	90.0	4.365	3.503	80.2	3.087	863	—	—
2023	29.526	28.186	95.5	3.697	3.137	84.9	1.341	560	1.8	-10.4
2024	28.702	25.768	89.8	3.026	2.728	90.2	2.934	298	-8.6	-13.0
2025	28.340	23.616	83.3	2.771	2.411	87.0	4.723	360	-8.3	-11.6

Source: Developed by the authors based on Foxtrot operational production records

Table 4 shows a sustained decline in realized production performance during the four-year observation period. The production trajectory exhibits a non-linear degradation pattern. Following temporary stabilization in 2023, production performance entered a phase of accelerated decline during 2024–2025. Fluid production achievement improved from 90.0% in 2022 to 95.5% in 2023, indicating short-term operational recovery. However, this improvement was not sustained, with performance declining to 89.8% in 2024 and further to 83.3% in 2025, representing the lowest annual achievement recorded during the study period. A similar pattern was observed in oil production realization. Actual oil output declined from 3,503 bopd in 2022 to 2,411 bopd in 2025, corresponding to an overall reduction of approximately 31.2%. The decline in production realization was accompanied by increasing fluid losses. After reaching its lowest point in 2023 (1,341 bfpd), fluid loss increased sharply to 2,934 bfpd in 2024 and 4,723 bfpd in 2025. This escalation indicates intensifying deviation between planned and realized production performance. To further examine production consistency, monthly production realization during 2025 is presented in Table 5.

As shown in Table 5, monthly production remained below target throughout all twelve months of 2025. The persistence of underachievement across the annual production cycle indicates that production deviation was structural rather than episodic. The most severe deviation occurred in May, when fluid production performance declined to 76.2%, corresponding to a production shortfall of 6,513 bfpd. Although temporary improvements were observed in August (88.2%) and November (86.2%), these recoveries were not sustained. Oil production exhibited comparatively narrower monthly fluctuation. However, underperformance remained consistent across all months. The highest oil realization was recorded in November (95.5%), yet this remained below full target achievement. Comparison between tested well capability and realized production is presented in Table 6.

Table 5. Longitudinal productivity performance of Foxtrot Flow Station (2022–2025)

Month	Base Fluid (bfpd)	Actual Fluid (bfpd)	Fluid Gap	Fluid Perform (%)	Base Oil (bopd)	Actual Oil (bopd)	Oil Gap	Oil Perform (%)
Jan	28.470	23.466	-5.004	82.4	2.975	2.574	-401	86.5
Feb	27.829	22.870	-4.959	82.2	2.895	2.511	-384	86.7
Mar	27.250	24.003	-3.247	88.1	3.090	2.630	-460	85.1
Apr	27.332	23.314	-4.018	85.3	2.840	2.529	-311	89.1
May	27.332	20.819	-6.513	76.2	2.745	2.385	-360	86.9
Jun	29.200	23.973	-5.227	82.1	2.785	2.410	-375	86.5
Jul	28.560	23.961	-4.599	83.9	2.870	2.379	-491	82.9
Aug	27.837	24.542	-3.295	88.2	2.730	2.294	-436	84.0
Sep	30.120	24.568	-5.552	81.6	2.635	2.327	-308	88.3
Oct	29.262	23.440	-5.822	80.1	2.635	2.229	-406	84.6
Nov	28.254	24.363	-3.891	86.2	2.545	2.431	-114	95.5
Dec	28.630	24.059	-4.571	84.0	2.505	2.225	-280	88.8
YTD	28.340	23.616	-4.723	83.3	2.771	2.411	-360	87.0

Source: Developed by the authors based on monthly production reports

Table 6. Well test versus realized production performance (2025)

Month	Well Count	Test Oil (bopd)	Act. Oil (Bopd)	Oil Gap	Oil Realiz (%)	Test Fluid (bfpd)	Act. Fluid (bfpd)	Fluid Gap	Fluid Realiz (%)
Jan	20	2.971	2.574	-397	86.6	26.045	23.466	-2.579	90.1
Feb	20	2.893	2.511	-382	86.8	25.381	22.870	-2.511	90.1
Mar	21	2.818	2.630	-188	93.3	24.618	24.003	-615	97.5
Apr	20	2.820	2.529	-291	89.7	25.031	23.314	-1.717	93.1
May	20	2.742	2.385	-357	87.0	24.847	20.819	-4.028	83.8
Jun	21	2.715	2.410	-305	88.8	25.501	23.973	-1.528	94.0
Jul	22	2.786	2.379	-407	85.4	25.772	23.961	-1.811	93.0
Aug	23	2.583	2.294	-289	88.8	24.364	24.542	178	100.7
Sep	23	2.757	2.327	-430	84.4	26.700	24.568	-2.132	92.0
Oct	23	2.631	2.229	-402	84.7	25.967	23.440	-2.527	90.3
Nov	21	2.540	2.431	-109	95.7	25.430	24.363	-1.067	95.8
Dec	21	2.502	2.225	-277	88.9	25.881	24.059	-1.822	93.0
Avg.	21	2.730	2.411	-319	88.3	25.878	24.031	-1.847	92.8

Source: Developed by the authors based on well testing and production realization records

Table 6 indicates persistent deviation between tested well capability and realized operational output. Average realization reached 88.3% for oil and 92.8% for fluid. Only August recorded fluid realization exceeding tested potential. These findings indicate recurring production conversion losses.

Table 7 indicates that unplanned operational losses dominated annual production deviation. Tubing obstruction represented the dominant annual production loss contributor, accounting for 52.89% of total loss. Subsea hydrocarbon leakage and bottleneck restrictions were the second and third largest contributors. Interview responses consistently identified gas lift instability, tubing restriction development, and pressure-flow imbalance as recurring productivity constraints. Overall, productivity findings indicate persistent output underachievement and conversion inefficiencies whose broader operational significance is synthesized.

Table 7. Unplanned Production Loss Distribution (2025)

Loss Cause	Oil Loss (bbl)	Percentage (%)
Tubing Obstruction	76.559	52.89
HC Leak at Subsea	24.182	16.71
Bottleneck	9.860	6.81
Water Cut Increase	7.712	5.33
GLV Malfunction	6.523	4.51
Pressure Depletion	3.456	2.39
Vibration	2.223	1.54
ESD / PSD	2.029	1.40
HC Leak at Surface	1.936	1.34
Others	270	0.19
Planned Losses	9.859	6.81
Total	144.750	100.00

Source: Developed by the authors based on well testing and production realization records

Because these output drops are inherently tied to physical field activities, mapping productivity losses requires a granular review of both visible downtime incidents and hidden process inefficiencies across the asset network. Operational performance was assessed through evaluation of disruption frequency, downtime patterns, operational continuity constraints, and non-downtime efficiency losses across well and plant operations. The annual operational disruption profile is presented in Table 8.

Table 8. Annual operational disruption profile (2022–2025)

Year	Well Op. Disruption	Plant Op. Disruption	Total Shutdown	Operational Pattern
2022	21	13	34	High system instability
2023	11	4	15	Temporary stabilization
2024	14	1	15	Well-side disruption dominance
2025	11	6	17	Recurring operational interruption

Source: Developed by the authors based on operational event records

Table 8 shows Operational disruptions persisted throughout the study period. A substantial reduction in shutdown frequency occurred between 2022 and 2023, declining from 34 to 15 events. However, this reduction was not followed by sustained production recovery. Well-side disruptions consistently exceeded plant-related disruptions. This pattern indicates concentration of operational continuity constraints within upstream production systems. Detailed downtime-related operational constraints during 2025 are presented in Table 9.

Table 9. Downtime-related operational constraints by production loss (2025)

Operational Constraint	Oil Loss (bbl)	Shut-In Hours	Frequency
Subsea pipeline leak	24.182	4.971	10
Bottleneck after subsea leak repair	9.645	2.427	5
GLV malfunction	6.523	1.287	6
Surface hydrocarbon leak	1.936	337	9
Turbine generator loss power	1.464	185	3
Instrumentation/control system failure	425	54	9

Source: *Developed by the authors based on operational downtime records*

Table 9 indicates that subsea integrity-related disruption represented the dominant operational constraint during 2025. Subsea pipeline leakage generated the highest production loss and longest shut-in duration. Bottleneck restrictions following repair activities represented the second-largest contributor. GLV malfunction ranked third. Plant-side disruptions produced comparatively lower operational impact. Although these events occurred repeatedly, their operational impact remained secondary relative to well-side integrity and flow assurance constraints. Non-downtime operational constraints are presented in Table 10.

Table 10. Non-downtime operational constraints by production loss (2025)

Constraint	Oil Loss (bbl)	Contribution (%)
Gas lift injection not optimum	74.294	51.32
Post-intervention low performance	1.170	0.81
Tubing/flowline scale-up	614	0.42
Limited associated gas	273	0.19
Flowline backpressure	144	0.10

Source: *Developed by the authors based on operational surveillance records*

Table 10 shows that the largest operational losses occurred without formal shutdown conditions. The largest operational losses occurred without formal shutdown conditions. Suboptimal gas lift injection accounted for 51.32% of annual non-downtime operational loss. This finding indicates that production degradation frequently developed through reduced operational effectiveness rather than complete interruption. Interview responses consistently described strong interdependency between gas lift distribution stability, pressure balance, and production continuity.

Managing these complex upstream constraints inevitably drives up the technical demands on the engineering crew, creating an escalating corrective workload that impacts the overall cost efficiency of the asset. Maintenance performance was evaluated to assess the extent to which maintenance activities supported operational continuity under mature-field conditions. The analysis focused on maintenance execution trends, production-loss attribution, recurring reliability constraints, and intervention outcomes. Maintenance performance is particularly important in mature offshore assets because infrastructure aging increases exposure to degradation mechanisms requiring timely and effective reliability assurance. The annual maintenance execution profile is presented in Table 11.

Table 11. Maintenance execution profile (2022–2025)

Year	Planned Maintenance Activities	Unplanned Corrective Activities	Maintenance Pattern
2022	High	Moderate	Stabilization effort
2023	High	Low	Temporary optimization
2024	Moderate	Increasing	Emerging reliability degradation
2025	Moderate	High	Corrective maintenance dominance

Source: *Developed by the authors based on maintenance operational records*

Table 11 indicates increasing maintenance pressure during the observation period. During 2022–2023, maintenance activity was predominantly preventive and planned, coinciding with relatively improved operational stability. Beginning in 2024, corrective intervention requirements increased alongside recurring integrity-related operational constraints. This pattern reflects growing reliability pressure associated with aging offshore infrastructure. Major maintenance-related production loss contributors during 2025 are presented in Table 12.

Table 12. Maintenance-related production loss profile (2025)

Loss Category	Operational Cause	Oil Loss (bbl)	Shut-In Hours	Contri-bution (%)	Maintenance Interpretation
Planned	Well surveillance	4.123	1,095	2.85	Controlled operational monitoring activity
	Pre-SIMOP / SIMOP	3.772	926	2.61	Scheduled operational coordination
	Planned maintenance	1.964	475	1.36	Routine preventive intervention
Subtotal Planned		9.859	2.496	6.82	Controlled scheduled intervention exposure
Unplanned	HC leak at subsea	24.182	4.971	16.71	Major integrity restoration burden
	Bottle neck	9.860	2.471	6.81	Post-repair operational restriction
	GLV malfunction	6.523	1.287	4.51	Artificial lift corrective intervention
	TBG. Comm./Leaks	362	222	0.25	Tubing corrective intervention
	Mechanical	35	15	0.02	Minor corrective event
	Integrity	21	5	0.01	Localized corrective restoration
Subtotal Explicit Unplanned		40.983	8.971	28.31	Corrective reliability burden
Latent Degradation	Tubing obstruction	76.559	0	52.89	Hidden production loss mechanism
Total		144.757	12.686	100.00	Integrated maintenance-reliability exposure

Source: *Developed by the authors based on Production Loss Management System and maintenance intervention records*

Table 12 shows that the production-loss profile reveals that planned intervention contributed only 6.8% of total annual loss. This indicates that scheduled maintenance activities remained operationally controlled. Unplanned corrective disruption accounted for 28.3%, reflecting increasing intervention burden associated with integrity-related reliability challenges. The dominant contributor, however, was latent degradation loss, which represented 52.9% of annual production loss without associated shut-in hours. This pattern indicates that Foxtrot's principal maintenance challenge emerged through hidden degradation mechanisms operating under nominal system availability. Maintenance reliability outcomes are further reflected in recurring equipment failure categories. These are presented in Table 13.

Table 13. Recurring equipment reliability issues (2025)

Equipment/System	Failure Pattern	Operational Impact
Gas Lift Valve system	Recurrent malfunction	Artificial lift instability
Subsea pipeline system	Integrity degradation	Major shutdown and loss production
Flowline system	Progressive restriction	Pressure imbalance
Instrumentation system	Intermittent malfunction	Operational control disturbance
Turbine support system	Periodic interruption	Reduced processing continuity

***Source:** Developed by the authors based on maintenance failure reports*

Table 13 indicates that recurring reliability constraints were concentrated within gas lift systems, subsea pipeline infrastructure, and flowline systems. Interview responses consistently described increasing troubleshooting complexity and repeated intervention requirements. Operational personnel further reported that certain systems were frequently restored to minimum operability rather than full performance capability. Overall, the maintenance findings indicate that Foxtrot's reliability challenge lies less in excessive planned shutdown exposure and more in the increasing difficulty of fully restoring optimal performance under mature infrastructure conditions. Economic performance was assessed through longitudinal production trends, deferred production losses, and operational evidence indicating changing resource intensity. Because detailed cost allocation data were unavailable, the analysis focuses on operational indicators implying economic performance conditions. The longitudinal production trend is presented in Table 14.

Table 14. Longitudinal production trend and economic implication (2022–2025)

Year	Actual Oil Prod. (BOPD)	Annual Decline (%)	Oil Perf. (%)	Economic Implication
2022	3,503	—	80.2	Baseline production pressure
2023	3,137	-10.4	84.9	Moderate revenue contraction
2024	2,728	-13.0	90.2	Accelerated production compression
2025	2,411	-11.6	87.0	Sustained economic pressure

***Source:** Developed by the authors based on production performance records*

Table 14 shows that actual oil production declined consistently throughout the observation period, decreasing by approximately 31.2% between 2022 and 2025. Although relative production performance improved during selected periods, absolute production volume continued to contract. This indicates progressive reduction in production value generation capacity. The economic implications of production loss distribution are presented in Table 15.

Table 15. Production loss contributors with economic implications (2025)

Loss Category	Oil Loss (BOPD)	Contribution (%)	Economic Implication
Tubing obstruction	76.559	52.89	Sustained deferred production
Subsea pipeline leak	24.182	16.71	High repair and restoration burden
Bottleneck restriction	9.860	6.81	Flow efficiency reduction
Water cut increase	7.712	5.33	Reduced production quality
GLV malfunction	6.523	4.51	Recurrent intervention requirement
Planned maintenance	1.964	1.36	Controlled operational expenditure

Source: *Developed by the authors based on Production Loss Management System records*

Table 16 indicates that Tubing obstruction represented the dominant source of unrealized production value, followed by subsea leakage and bottleneck restriction. Interview responses consistently described increasing operational effort required to sustain production continuity. These findings indicate growing economic pressure characteristic of mature offshore production systems, where declining output coincides with rising intervention intensity. Overall, Foxtrot appears to be experiencing progressive cost-efficiency compression driven by deferred production accumulation and increasing reliability burden.

While technical bottlenecks and financial pressures intensfied, safety protocols and organizational discipline remained strongly decoupled from these field degradation loops. HSSE performance was evaluated to assess operational safety, environmental control, and organizational resilience under increasing technical and operational complexity. Foxtrot's HSSE performance indicators are presented in Table 16.

Table 16. HSSE performance indicators in ending 2025

Indicator	Achievement	Operational Interpretation
No Lost Time Injury (NLTI)	6.528 days	Sustained personnel safety performance
Safe man-hours	9.187,858 hours	Consistent operational exposure control
HSSE campaign activities	312 activities	Strong safety communication intensity
PEKA observations	14.476 reports	High proactive hazard identification
ACTRIS observations	38 reports	Active critical risk reporting
Emergency drills	17 activities	Sustained emergency preparedness

Source: *Developed by the authors based on HSSE operational records*

Table 16 shows that Foxtrot maintained strong overall HSSE performance throughout the observation period. The facility recorded 6,528 days without Lost Time Injury and accumulated 9,187,858 safe man-hours. High proactive reporting activity further indicates strong hazard-identification culture. Preventive and preparedness-oriented HSSE activities indicators are presented in Table 17.

Table 17. HSSE preventive and preparedness activities

Activity Category	Frequency	HSSE Function
General HSSE meeting	23	Strategic safety alignment
General sharing session	38	Operational knowledge reinforcement
Safety stand-down and lessons learned	79	Incident prevention learning
HSSE sharing	107	Routine safety awareness
Healthy sharing	48	Workforce health promotion
Emergency drill	17	Emergency response readiness

Source: *Developed by the authors based on HSSE operational records*

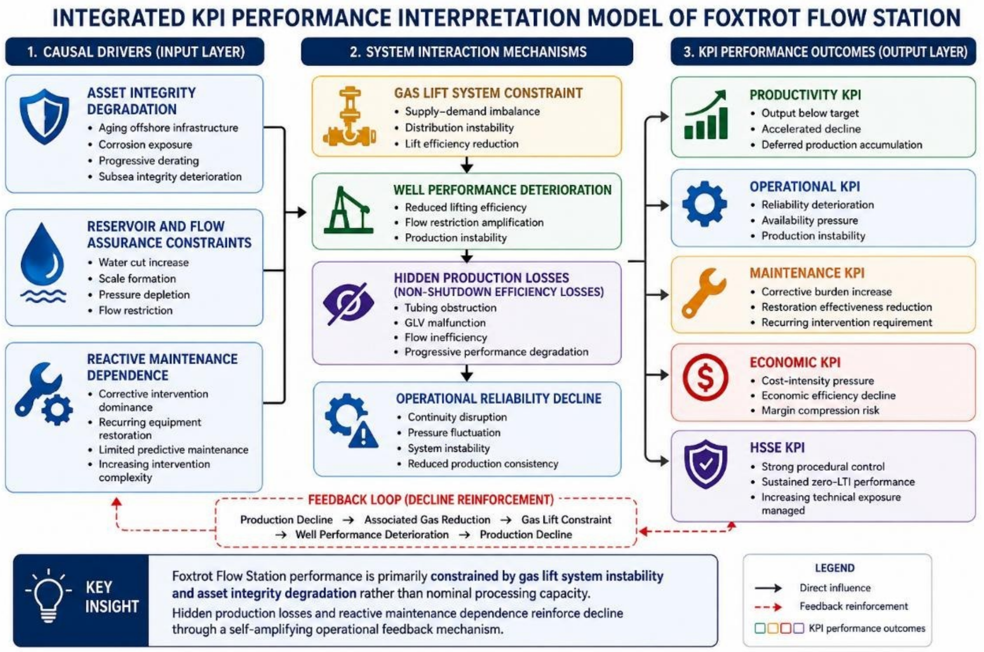
Table 17 indicates Preventive and preparedness-oriented HSSE activities were implemented consistently. Interview responses reinforced the presence of strong procedural safety discipline and cross-functional risk communication. Importantly, recurring operational and maintenance constraints did not translate into a deterioration of safety outcomes. This indicates that strong workforce discipline acts as a stabilizing buffer under high technical stress. This pattern aligns with foundational human resource frameworks demonstrating that structured work environments and strict organizational discipline directly safeguard baseline employee performance even during operational disruptions (Dewa, 2023). Overall, the HSSE performance results indicate that Foxtrot maintained strong safety management effectiveness throughout the observation period. The findings suggest that while operational and maintenance performance experienced increasing pressure, safety governance systems remained robust and continued to provide effective protection for personnel and operational activities.

To synthesize cross-dimensional findings, Table 18 summarizes the dominant performance patterns observed across all KPI dimensions. Table 18 show that the integrated findings indicate that Foxtrot's performance cannot be adequately interpreted through isolated KPI evaluation. Instead, the results reveal strong systemic interdependence among productivity, operational reliability, maintenance performance, economic pressure, and HSSE resilience.

Table 18. Cross-dimensional synthesis of KPI findings

KPI Dimension	Dominant Finding	Primary Constraint	Systemic Implication
Productivity	Persistent output shortfall	Tubing obstruction and gas lift inefficiency	Reduced production deliverability
Operational	Well-side disruption dominance	Subsea integrity degradation and flow instability	Production continuity loss
Maintenance	Increasing integrity-restoration burden	Aging infrastructure and latent degradation	Reliability assurance pressure
Economic	Production compression	Deferred production accumulation	Cost-efficiency deterioration
HSSE	Sustained strong performance	No critical deterioration observed	Organizational resilience

An integrated KPI performance interpretation model was developed based on the triangulation of operational records, production loss analysis, and qualitative interview evidence.



Foxtrot Flow Station performance is primarily **constrained by gas lift system instability and asset integrity degradation** rather than nominal processing capacity. Hidden production losses and reactive maintenance dependence reinforce decline through a self-amplifying operational feedback mechanism.

Source: *Developed by the author based on triangulation of operational data, production loss records, and interview findings.*

Figure 4. Integrated KPI Performance Interpretation Model of Foxtrot Flow Station

Figure 4 illustrates the systemic interaction among three principal causal drivers, namely asset integrity degradation, flow assurance constraints, and corrective reliability burden. These factors are interconnected and collectively influence operational performance within the system. Asset integrity degradation contributes to declining equipment condition and increased vulnerability to failures, while flow assurance constraints hinder the efficient transportation and processing of production streams. As operational disruptions become more frequent, the corrective reliability burden increases, requiring greater maintenance efforts, resources, and unplanned interventions to sustain system functionality. The dynamic interaction among these drivers creates a reinforcing cycle in which deteriorating asset conditions and flow-related challenges elevate corrective maintenance demands, ultimately affecting overall reliability, efficiency, and production effectiveness. These drivers propagated through two dominant internal mechanisms: gas lift system instability and hidden production loss accumulation.

A central finding is the dominance of latent degradation losses occurring without associated shutdown exposure. This indicates that Foxtrot's principal production constraints frequently emerged through hidden operational inefficiencies rather than explicit maintenance interruption. These hidden losses explain the persistent discrepancy between tested production capability and realized operational output. The cascading effects of these mechanisms were observed across all performance dimensions. Productivity declined through reduced deliverability, operational continuity deteriorated through integrity-related disruption, maintenance performance experienced increasing corrective burden, and economic pressure intensified through deferred production accumulation. In contrast, HSSE performance remained comparatively resilient due to strong procedural governance and organizational safety discipline.

Overall, the integrated findings indicate that Foxtrot is experiencing systemic maturity-driven operational pressure characterized by self-reinforcing interaction among latent degradation, reliability burden, and declining production efficiency. The results suggest that long-term performance improvement will depend primarily on predictive degradation detection, gas lift stabilization, and proactive integrity reinforcement. These findings provide the empirical foundation for the discussion presented in the following chapter.

5. | DISCUSSION

This study evaluated the operational performance of Foxtrot Flow Station through an integrated Key Performance Indicator (KPI) framework encompassing productivity, operational reliability, maintenance effectiveness, economic implications, and HSSE performance. The findings demonstrate that Foxtrot's declining operational performance cannot be attributed to a single technical deficiency. Rather, the observed deterioration reflects systemic interaction among asset integrity degradation, gas lift instability, hidden production losses, and increasing dependence on corrective operational response. The integrated interpretation further indicates that while productivity, operational continuity, maintenance effectiveness, and economic efficiency exhibited progressive deterioration, HSSE performance remained comparatively resilient. This chapter discusses these findings in relation to mature offshore production management literature and examines their broader implications for sustaining late-life offshore production systems.

When analyzing the core components of this declining performance trajectory, the primary structural issue manifests as a system-constrained reliability problem rather than a standard reservoir dynamics event. A central finding of this study is that Foxtrot Flow Station's production decline should not be interpreted solely as a consequence of natural reservoir depletion. Although declining reservoir pressure and increasing water cut are expected characteristics of mature offshore assets, the evidence indicates that Foxtrot's production deterioration was substantially amplified by operational reliability constraints. The longitudinal production analysis showed persistent underachievement against annual production targets, with realized oil production declining by more than 30% during the observation period. Importantly, this decline occurred despite well test performance that frequently indicated production capability close to planned levels. This discrepancy suggests that production limitations were concentrated within operational delivery mechanisms rather than intrinsic subsurface incapacity. The findings therefore support reliability-centered perspectives arguing that mature asset decline is often accelerated by system-level degradation rather than geological depletion alone (Ahmed, 2019; Jardine et al., 2006; Eti et al., 2006).

The integrated KPI analysis further identified a reinforcing decline mechanism linking reduced production, lower associated gas availability, weakened gas lift support, and further productivity deterioration. This self-reinforcing feedback loop explains why production decline persisted despite repeated intervention efforts and extends conventional interpretations of late-life offshore decline beyond reservoir engineering perspectives. For Foxtrot, the dominant challenge is therefore not simply depletion management but interruption of systemic reliability constraints. This implies that production recovery strategies should prioritize operational reliability restoration particularly gas lift stabilization and integrity reinforcement rather than relying solely on conventional production enhancement intervention.

Hidden Production Losses and Gas Lift Dynamics

The core operational driver compounding this structural decline is the prevalence of hidden production losses, which act as a silent constraint alongside the facility's prominent gas lift dependencies. One of the most significant findings of this study is the dominant contribution of hidden production losses to Foxtrot’s operational deterioration. Unlike conventional losses associated with formal shutdown events, these losses accumulated progressively under nominally active operating conditions through tubing obstruction, gas lift inefficiency, flow restriction, and gradual well performance degradation. This finding reveals an important blind spot in mature offshore asset performance management. Traditional offshore performance frameworks frequently emphasize downtime-based indicators such as shutdown frequency and outage duration (Mobley, 2002), yet the Foxtrot case demonstrates that substantial production degradation may occur without corresponding increases in formally recorded downtime. Tubing obstruction, which represented the largest share of annual production loss, largely developed without associated shut-in events, confirming that operational availability did not necessarily translate into effective production deliverability.

The discrepancy between favorable well test capability and lower realized production further reinforces this interpretation. Static capability measurement proved insufficient for capturing dynamic efficiency deterioration occurring under live operating conditions. This finding extends reliability literature suggesting that mature asset deterioration often emerges through progressive efficiency loss rather than catastrophic failure events (Tsang, 2002). Operationally, hidden losses are especially problematic because they frequently remain undetected long enough to generate substantial cumulative production deferment. The findings therefore suggest that mature offshore assets require broader surveillance capability emphasizing continuous flow assurance diagnostics, gas lift monitoring, and real-time production efficiency tracking to complement conventional uptime-based reliability indicators.

The findings consistently identify gas lift dependency as the most critical operational constraint affecting Foxtrot Flow Station's overall performance. This is structurally consistent with mature offshore production systems, where declining reservoir pressure progressively increases reliance on artificial lift performance to sustain production continuity (Lea & Nickens, 2008). Operational evidence showed that gas lift instability manifested through injection imbalance, valve malfunction, associated gas limitation, and uneven lift distribution, all of which directly reduced lifting efficiency and amplified flow restriction effects. The integrated analysis demonstrated that gas lift instability acted not as an isolated disturbance but as the central mechanism through which technical degradation propagated into productivity decline. A particularly important contribution of this study is the identification of a feedback relationship between declining production and gas lift limitation. Reduced production lowered associated gas availability, constraining gas lift distribution capability and further suppressing well productivity. This explains why production deterioration persisted despite repeated intervention. The discrepancy between tested well capability and actual field realization further confirms that Foxtrot's principal limitation was not reservoir potential but the inability of the gas lift system to provide stable operational support. This finding is consistent with prior artificial lift literature (Brown, 1984) while extending it by demonstrating how gas lift instability can simultaneously affect multiple KPI dimensions. Managerially, this positions gas lift optimization as the highest-leverage intervention point for restoring operational sustainability.

Hidden Production Losses as the Dominant Performance Constraint

One of the most significant findings of this study is the dominant contribution of hidden production losses to Foxtrot's operational deterioration. Unlike conventional losses associated with formal shutdown events, these losses accumulated progressively under nominally active operating conditions through tubing obstruction, gas lift inefficiency, flow restriction, and gradual well performance degradation. This finding reveals an important blind spot in mature offshore asset performance management. Traditional offshore performance frameworks frequently emphasize downtime-based indicators such as shutdown frequency and outage duration (Mobley, 2002), yet the Foxtrot case demonstrates that substantial production degradation may occur without corresponding increases in formally recorded downtime. Tubing obstruction, which represented the largest share of annual production loss, largely developed without associated shut-in events, confirming that operational availability did not necessarily translate into effective production deliverability.

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To transform these operational friction points into long-term gains, the asset must establish an integrated sustainability strategy that leverages its existing organizational strengths while contributing new paradigms to global production literature. The integrated findings demonstrate that Foxtrot’s operational challenges cannot be effectively addressed through isolated corrective action. The observed decline reflects systemic interaction among technical degradation, gas lift dependency, hidden production losses, and maintenance limitations, indicating that sustainable performance recovery requires coordinated system-level intervention. A primary implication concerns performance monitoring architecture. Conventional systems emphasizing visible shutdown events are insufficient for mature offshore assets where hidden efficiency deterioration dominates. Management systems must therefore incorporate more granular surveillance capability capable of detecting early-stage degradation before these conditions evolve into structural production constraints. Strategic intervention should prioritize gas lift stabilization through dynamic allocation optimization, enhanced valve integrity management, continuous injection monitoring, and associated gas forecasting.

The findings also highlight the need for maintenance strategy transformation. Mature offshore sustainability increasingly depends on predictive reliability capability rather than corrective response capacity. Strategic maintenance investment should therefore be evaluated according to long-term reliability recovery potential rather than immediate continuity restoration alone. Importantly, the divergence observed between deteriorating operational reliability and sustained HSSE performance demonstrates that Foxtrot retains strong procedural governance and organizational discipline despite technical strain. Prior organizational literature highlights that aligning a disciplined work environment with targeted workforce tasks is a prerequisite for sustaining core performance under challenging conditions (Dewa, 2023). This suggests that the organizational capability required for operational recovery already exists and can be redirected toward reliability-centered operational transformation. More broadly, the findings indicate that mature offshore asset management must evolve from short-term production stabilization toward integrated reliability stewardship if long-term operational viability is to be preserved.

This study contributes to offshore production performance literature in several ways. First, it extends mature-field performance evaluation by demonstrating the analytical value of integrated multidimensional KPI assessment within a systems-thinking framework. Second, it provides empirical support for the concepts of system-constrained production and hidden production losses, showing how nominal operational availability may mask substantial production inefficiency. Third, it contributes empirical insight from the context of an Indonesian mature offshore asset, which remains underrepresented in international offshore operations literature. Collectively, these contributions advance understanding of how mature offshore production decline emerges through interacting operational mechanisms rather than isolated technical failure. The findings suggest that future offshore performance research should increasingly adopt integrated reliability-oriented analytical frameworks capable of capturing the systemic nature of late-life production deterioration.

6. | CONCLUSION

This study evaluated the operational performance of Foxtrot Flow Station through an integrated Key Performance Indicator (KPI) framework encompassing productivity, operational reliability, maintenance effectiveness, economic implications, and Health, Safety, Security, and Environment (HSSE) performance. Using longitudinal operational data and qualitative evidence from cross-functional operational personnel, the study examined how multidimensional operational constraints influence performance sustainability in a mature offshore production system. The findings demonstrate that Foxtrot Flow Station's declining production performance cannot be explained solely by natural reservoir depletion. Instead, performance deterioration emerged through systemic interaction among asset integrity degradation, gas lift instability, hidden production losses, and increasing dependence on corrective operational response.

The study identifies Foxtrot as operating under a condition of system-constrained production, where available production capability could not be fully translated into realized operational output due to delivery system inefficiencies. A major finding is that hidden production losses particularly tubing obstruction, gas lift imbalance, and flow restriction represented the dominant source of performance degradation. Gas lift instability emerged as the critical operational bottleneck linking productivity decline, operational inefficiency, maintenance burden, and economic pressure. The findings also reveal maintenance strategy misalignment, where interventions increasingly restored minimum operability rather than full reliability performance. Despite these operational challenges, HSSE performance remained resilient, indicating that strong procedural governance and organizational discipline were maintained throughout the observation period. Overall, this study concludes that Foxtrot is experiencing systemic maturity-driven operational pressure that requires transition from reactive operational stabilization toward integrated reliability-centered management. This study contributes to offshore production performance literature by demonstrating the analytical value of integrated KPI evaluation and by providing empirical evidence for the concepts of hidden production losses and system-constrained production in mature offshore assets.

To translate these core analytical conclusions into actionable industrial solutions, a series of targeted managerial interventions must be deployed across the asset's primary engineering workflows. First, operational improvement should prioritize gas lift system stabilization through dynamic gas allocation optimization, enhanced valve reliability management, and continuous injection surveillance. Second, maintenance strategy should transition toward predictive and reliability-centered approaches emphasizing condition-based monitoring and restoration-effectiveness validation. Third, performance monitoring systems should be expanded beyond conventional downtime indicators to capture hidden production losses through continuous operational efficiency diagnostics. More broadly, Foxtrot should adopt an integrated reliability stewardship approach aligning operational, maintenance, engineering, and integrity management functions to interrupt self-reinforcing decline mechanisms and sustain long-term asset performance.

While these recommendations provide a clear operational roadmap for asset stabilization, full deployment must be contextualized within the baseline boundaries and prospective pathways of this research. This study is limited by its single-case study design and the absence of detailed financial expenditure data for direct economic ratio analysis. In addition, the systemic relationships identified were interpreted qualitatively rather than modeled quantitatively. Future research should examine similar mature offshore assets through comparative multi-case analysis, integrate quantitative system dynamics modeling, and explore the application of predictive digital surveillance technologies for improving operational reliability and production sustainability in late-life offshore production systems.

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The authors declare that there is no conflict of interest.

Ethical Approval and Originality Statement

Ethical approval was obtained for this study. The manuscript represents original work and has not been previously published, nor is it under consideration by another journal.

Data Disclosure Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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