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Model for Inventory Availability and Plant Uptime Improvement in Energy Facilities

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Abstract- Ensuring uninterrupted operations and optimal performance in energy facilities requires effective management of inventory and plant uptime. Interruptions due to equipment unavailability, delayed maintenance, or supply chain disruptions can result in significant financial losses, operational inefficiencies, and safety risks. This paper presents a comprehensive model for inventory availability and plant uptime improvement that integrates demand forecasting, inventory optimization, maintenance planning, and digital monitoring to enhance operational reliability in energy facilities. The model emphasizes a proactive and data-driven approach, moving beyond reactive replenishment and ad hoc maintenance practices. Central to the model is inventory availability management, which aligns stock levels of critical spares, consumables, and maintenance materials with operational requirements and risk assessments. Predictive demand forecasting, based on historical consumption, production schedules, and equipment criticality, informs optimal stock levels, safety buffers, and reorder points. Inventory segmentation techniques, differentiating critical, strategic, and routine items, allow resource prioritization and cost-effective stocking strategies. Integration with plant maintenance schedules ensures that required components are available for planned and preventive maintenance activities, minimizing unplanned downtime. The model also incorporates plant uptime optimization through preventive and predictive maintenance practices, real-time condition monitoring, and performance tracking. Linking inventory management with maintenance planning enables timely interventions and reduces operational disruptions. Key performance indicators, such as mean time between failures, equipment availability, and stock-out frequency, provide actionable insights for continuous improvement. The framework promotes digital enablement, including enterprise resource planning (ERP) integration and data analytics, to monitor inventory levels, track asset performance, and support decision-making. By applying this model, energy facilities can achieve higher operational reliability, reduce costs associated with unplanned downtime, and enhance overall plant performance. Additionally, optimized inventory and maintenance practices support safety, regulatory compliance, and sustainable operational outcomes.

Keywords: Inventory Availability; Plant Uptime; Energy Facilities; Preventive Maintenance; Predictive Analytics; Operational Reliability; ERP Integration; Supply Chain Optimization.

I. INTRODUCTION

Energy facilities, including power plants, refineries, and renewable energy installations, operate in highly complex and capital-intensive environments where reliability, safety, and efficiency are critical to organizational performance (Hashmi *et al*., 2016; Rees, 2016). These facilities rely on intricate systems of mechanical, electrical, and control equipment, all of which require regular maintenance and a steady supply of critical components to function effectively. Operational challenges in energy facilities often arise from equipment failures, supply chain disruptions, unplanned maintenance, and fluctuating energy demand (Sheffi, 2015; Khosrojerdi *et al*., 2016). These challenges can lead to unanticipated downtime, safety hazards, and increased operational costs, creating significant financial and reputational risks for facility operators.

One of the primary operational challenges is maintaining continuous plant uptime, which directly impacts energy production, system reliability, and overall facility efficiency (Myerson *et al*., 2015; Stamatis, 2017). Unplanned equipment failures or delays in maintenance can result in prolonged outages, reduced output, and potential safety incidents. In addition, energy facilities frequently face supply chain complexities due to the need for specialized spare parts, long procurement lead times, and reliance on a limited number of qualified suppliers (MacCarthy *et*

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al., 2016; Li *et al*., 2017). Without effective inventory management, critical components may be unavailable when needed, exacerbating downtime and hindering operational continuity (Kansanoja, 2016; Rose and Huyck, 2016). These challenges underscore the importance of integrating inventory availability with maintenance and operational planning to ensure that assets remain functional and reliable.

The importance of inventory availability and plant uptime extends beyond operational efficiency to encompass safety and cost control. Ensuring that critical spares, consumables, and maintenance materials are available reduces the risk of unplanned interruptions and minimizes emergency procurement costs, which are often higher due to expedited shipping or premium supplier charges (Moore *et al*., 2015; Andersson and Molin, 2017). Adequate inventory also supports preventive and predictive maintenance programs, enhancing asset reliability and prolonging equipment lifespan. Improved plant uptime contributes to consistent energy delivery, compliance with regulatory obligations, and maintenance of stakeholder confidence, particularly in industries where service continuity is essential (Slama et a., 2015; Enbar *et al*., 2016).

The rationale for developing an integrated model for inventory availability and plant uptime improvement lies in the need to address these operational challenges systematically. Traditional approaches often treat inventory management, maintenance scheduling, and operational planning as separate functions, leading to inefficiencies, misalignment, and delayed responses to emerging issues (Aro-Gordon and Gupte, 2016; Wan *et al*., 2017). An integrated model provides a holistic framework that links demand forecasting, inventory optimization, maintenance planning, and digital monitoring, enabling proactive decision-making and data-driven management. By combining these elements, the model aims to enhance operational reliability, reduce costs, and support safe and efficient facility operations (Wong and Zhou, 2015; Pärn *et al*, 2017).

Energy facilities face complex operational challenges that threaten uptime, safety, and cost efficiency (Kumar *et al*., 2016; Sajid *et al*., 2016). Optimizing inventory availability and plant uptime through an integrated model is essential for ensuring operational continuity, reducing financial risk, and enhancing overall performance. This approach positions procurement, inventory management, and maintenance as strategic enablers of resilient and high-performing energy operations.

II. METHODOLOGY

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology was applied to systematically identify, evaluate, and synthesize relevant evidence for the development of a model aimed at improving inventory availability and plant uptime in energy facilities. This methodological approach ensures transparency, rigor, and reproducibility, enabling a comprehensive review of both academic and industry sources to inform a robust, evidence-based framework.

A comprehensive literature search was conducted across multiple electronic databases, including Scopus, Web of Science, IEEE Xplore, and ScienceDirect, as well as industry publications and technical reports from energy organizations. The search strategy employed a combination of keywords and Boolean operators related to inventory management, spare parts availability, plant uptime, maintenance optimization, predictive maintenance, energy facility operations, and digital monitoring systems. Publications were limited to those published within the last fifteen years to ensure relevance to current operational practices and technological advancements.

Following identification, records were screened to remove duplicates and assess relevance based on titles and abstracts. Inclusion criteria focused on studies that addressed inventory management strategies, maintenance planning, uptime optimization, or integrated operational models in energy or comparable capital-intensive industries. Exclusion criteria removed studies lacking empirical or methodological rigor, purely theoretical discussions without practical application, or works unrelated to energy facility operations. Full-text assessment was then conducted to ensure alignment with the model's objectives, particularly the integration of inventory availability with maintenance planning and operational continuity.

Data extraction involved systematically capturing key themes, methodologies, outcomes, and contextual factors from selected studies. Emphasis was placed on approaches that linked inventory optimization to maintenance scheduling, predictive analytics, digital monitoring, and performance measurement. Information on best practices, technology adoption, and operational impacts was collated to inform model development.

The synthesized evidence guided the formulation of an integrated model that addresses inventory availability, predictive maintenance, and plant uptime in energy facilities. Using the PRISMA methodology ensures that the model is grounded in systematically reviewed, high-quality evidence, enhancing its applicability, reliability, and relevance for operational and strategic decision-making in energy facility management.

2.1 Conceptual Foundations

Effective operation of energy facilities requires a clear understanding of the conceptual foundations underpinning inventory availability and plant uptime. These concepts are central to maintaining operational continuity, ensuring safety, and optimizing costs. Conceptual clarity enables the development of a structured model that integrates inventory management, maintenance planning, and operational monitoring, thereby supporting strategic decision-making and value creation in energy facility management (Samaranayake and Laosirihongthong, 2016; Ali *et al*., 2017).

Inventory availability refers to the extent to which critical spares, consumables, and maintenance materials are present and accessible when needed to support ongoing operations. In energy facilities, critical components can range from electrical switchgear and turbines to pumps, valves, and control system modules. The availability of these items directly affects the ability to perform preventive and corrective maintenance, execute scheduled shutdowns, and respond to unforeseen equipment failures. Insufficient inventory can lead to extended downtime, increased emergency procurement costs, and potential safety hazards, while overstocking results in unnecessary capital tie-up and storage inefficiencies. Optimal inventory availability balances these considerations by ensuring that the right components are available at the right time, in appropriate quantities, and at a reasonable cost.

Plant uptime, in turn, is defined as the proportion of time during which equipment, systems, or the facility as a whole are fully operational and capable of delivering intended performance. High plant uptime reflects reliable operations, efficient maintenance practices, and effective coordination of resources, whereas low uptime indicates frequent disruptions, equipment failures, or operational inefficiencies. Plant uptime is a critical performance metric in energy facilities, where even brief interruptions can result in significant financial losses, safety risks, and regulatory non-compliance. Maintaining high uptime requires the integration of inventory management, maintenance scheduling, and real-time monitoring systems to anticipate and address potential disruptions proactively (Daily and Peterson, 2016; Bousdekis *et al*., 2017).

The primary objective of the proposed model is to reduce unplanned downtime by ensuring that critical inventory is available and maintenance activities are executed in a timely and coordinated manner. By aligning spare parts availability with equipment maintenance needs, the model minimizes delays caused by missing components, emergency procurement, or unscheduled shutdowns. This proactive approach enhances operational continuity, reduces production losses, and supports safety and regulatory compliance.

Another key objective is to optimize stock levels and maintenance scheduling. The model employs data-driven demand forecasting, inventory segmentation, and predictive analytics to determine optimal stock levels for critical and routine items. It also integrates inventory planning with preventive and predictive maintenance schedules, ensuring that components are available when needed and reducing unnecessary overstocking. Optimization of stock levels and maintenance timing improves resource efficiency, lowers holding costs, and enhances operational planning.

The model further aims to enhance operational reliability and cost efficiency. By ensuring that critical components are available and maintenance activities are planned and executed efficiently, energy facilities can maintain high levels of equipment performance, reduce the likelihood of equipment failure, and extend asset lifespan. Enhanced operational reliability not only minimizes downtime but also reduces costs associated with emergency repairs, expedited shipments, and production losses. Cost efficiency is achieved through a balanced approach to inventory management, maintenance planning, and utilization of predictive insights to allocate resources effectively (Stefanovic, 2015; Davis, 2016).

The conceptual foundations of the model for inventory availability and plant uptime improvement are grounded in the definitions of key concepts and clear operational objectives. Inventory availability ensures that necessary components are accessible, while plant uptime measures operational continuity. The model's objectives to reduce unplanned downtime, optimize stock levels and maintenance scheduling, and enhance reliability and cost efficiency provide a strategic framework for integrating inventory and maintenance management in energy facilities. By establishing these conceptual foundations, the model offers a structured approach to improving operational performance, safety, and financial outcomes.

2.2 Key Drivers for Inventory and Uptime Optimization

Optimizing inventory availability and plant uptime in energy facilities requires a deep understanding of the key drivers that influence operational reliability, cost efficiency, and safety. Energy facilities are capital-intensive environments with complex equipment, interdependent systems, and stringent performance expectations. Inefficient inventory management or unplanned equipment downtime can have cascading effects, including production losses, increased maintenance costs, regulatory non-compliance, and safety risks. Identifying and analyzing the drivers that affect inventory and uptime is therefore essential to designing a robust optimization model that enhances operational performance and mitigates risk (Velmurugan and Dhingra, 2025; Ivanov, 2017).

Equipment criticality is a primary driver of inventory and uptime optimization. Critical assets such as turbines, generators, pumps, compressors, and control systems have a disproportionate impact on facility operations if they fail. The availability of spares for these high-criticality components is essential to prevent extended downtime. Maintenance requirements, whether preventive, predictive, or corrective, further influence inventory needs. Equipment with high wear rates or complex maintenance procedures requires timely availability of specialized components to maintain uptime. By assessing the criticality of each asset and linking it to maintenance schedules, energy facilities can prioritize inventory allocation, optimize stock levels, and ensure that critical spares are available to minimize disruptions.

Supply chain reliability and lead times significantly affect inventory planning and plant uptime. Many energy facilities rely on specialized suppliers for critical components, some of which have long manufacturing and delivery lead times. Supply chain disruptions, whether due to geopolitical factors, transportation delays, or supplier capacity limitations, can result in unplanned downtime and operational inefficiencies. Optimization strategies must incorporate supplier reliability metrics, lead time variability, and contingency measures, such as dual sourcing or local stockpiling of critical components. Effective supply chain management ensures that maintenance and operational schedules are not compromised by unavailable parts or delayed deliveries (Seth and Panigrahi, 2015; Mello *et al.*, 2015).

Operational risk and safety are intrinsic drivers of inventory and uptime decisions in energy facilities. Equipment failures not only cause production losses but also pose hazards to personnel, the environment, and assets. Inventory strategies must account for the risk profile of assets, with higher safety-critical equipment requiring redundant spares and rapid availability. Risk-based maintenance and inventory planning frameworks prioritize critical systems, ensuring that operational continuity is maintained while mitigating potential safety incidents. Compliance with regulatory standards and internal safety protocols is also a key consideration, influencing both inventory stocking decisions and maintenance scheduling.

Cost and capital allocation considerations are critical drivers in balancing inventory availability with financial efficiency. Holding excessive stock ties up capital, incurs storage costs, and increases the risk of obsolescence, whereas insufficient inventory can lead to costly emergency procurement and downtime. Optimization requires data-driven assessment of trade-offs between carrying costs, procurement lead times, and criticality-based prioritization. Capital constraints also influence decisions about investing in predictive maintenance technologies, spare parts inventory, and strategic supplier agreements, all of which contribute to uptime and operational efficiency (Driessen *et al*., 2015; Jin *et al*., 2016).

Technological integration and data availability are increasingly pivotal in inventory and uptime optimization. Enterprise Resource Planning (ERP) systems, computerized maintenance management systems (CMMS), and predictive analytics platforms provide real-time visibility into inventory levels, equipment condition, and maintenance schedules. Data-driven decision-making allows for proactive identification of potential failures, precise demand forecasting, and alignment of inventory with maintenance needs. Integration of digital tools supports automated alerts for low stock, predictive maintenance triggers, and performance monitoring, enabling energy facilities to respond promptly to operational deviations and reduce unplanned downtime.

Equipment criticality, supply chain reliability, operational risk, cost constraints, and technological integration are key drivers of inventory availability and plant uptime optimization in energy facilities. By systematically assessing these drivers, organizations can develop data-driven, risk-informed strategies that ensure critical components are available when needed, maintenance is executed efficiently, and operational continuity is maximized. Understanding and addressing these drivers provides a foundation for enhanced reliability, cost efficiency, and safety in the management of complex energy assets, ensuring that inventory and uptime optimization delivers tangible operational and strategic benefits (Scott-Parker *et al*., 2015; Kalra and Paddock, 2016).

2.3 Model Structure for Inventory Availability and Uptime Improvement

Optimizing inventory availability and plant uptime in energy facilities requires a structured model that integrates demand forecasting, inventory planning, maintenance scheduling, and digital monitoring. A robust model addresses the challenges of unplanned downtime, supply chain disruptions, and equipment failures by ensuring that critical components and maintenance resources are available when needed, while maintaining cost efficiency and operational reliability. The proposed model structure emphasizes proactive, data-driven management of inventory and uptime to enhance facility performance and resilience.

Accurate demand forecasting is the cornerstone of inventory optimization. Historical consumption and usage patterns provide a baseline for predicting future requirements of spare parts, consumables, and maintenance materials. Analysis of past usage trends allows procurement and maintenance teams to identify patterns of wear and failure across critical assets, supporting timely replenishment decisions. Predictive analytics further enhances forecasting accuracy by incorporating real-time operational data, equipment condition monitoring, and maintenance schedules. Machine learning algorithms can detect anomalies, anticipate failure trends, and forecast component demand with higher precision than traditional methods (Liu *et al*., 2015; Gulenko *et al*., 2016). Safety stock and buffer determination is a complementary strategy, ensuring that critical items are available to absorb variability in lead times, consumption rates, or unexpected equipment failures. Optimizing safety stock balances cost efficiency with operational resilience, preventing both stock-outs and unnecessary capital tie-up.

Not all inventory items have the same operational or financial impact. The model emphasizes segmentation of inventory into critical, strategic, and routine items. Critical items include components whose unavailability would result in significant downtime or safety risks, requiring higher safety stock levels and proactive monitoring. Strategic items are important for operational continuity but may have alternative sources or longer lead times, while routine items involve low-cost consumables with minimal

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operational impact. Optimization of storage and replenishment strategies is achieved by aligning inventory policies with item criticality. For instance, critical items may be stocked at multiple locations or managed through consignment agreements with suppliers, whereas routine items follow standard reorder procedures. This prioritization ensures resource allocation aligns with operational risk and cost objectives.

Effective maintenance planning is essential to ensure that inventory availability directly supports operational uptime. Preventive maintenance programs are scheduled to align with available spares, tools, and labor, minimizing the risk of delays due to unavailable components. Predictive maintenance leverages real-time condition monitoring to anticipate equipment failures and trigger timely interventions, allowing inventory consumption to be synchronized with maintenance needs. Integration of maintenance schedules with operations and production plans ensures that equipment downtime is minimized, maintenance activities do not conflict with critical operational periods, and inventory is deployed efficiently (Basri *et al*., 2017; Piechnicki *et al*., 2017). This coordinated approach enhances plant reliability and reduces unplanned disruptions.

Digital integration is a critical enabler of the model. Enterprise Resource Planning (ERP) systems provide centralized visibility into inventory levels, procurement status, and maintenance schedules, facilitating data-driven decision-making. Digital dashboards and analytics enable real-time tracking of inventory availability, asset performance, and plant uptime, allowing managers to identify emerging issues and optimize resource allocation. Automated alerts for stock-outs, low inventory thresholds, or equipment performance deviations support proactive interventions, reducing unplanned downtime and enhancing operational efficiency. Additionally, integration of ERP and condition monitoring systems provides a seamless interface between inventory planning, maintenance execution, and operational management, promoting agility and responsiveness.

The model structure for inventory availability and plant uptime improvement integrates demand forecasting, inventory segmentation, maintenance planning, and digital monitoring to create a cohesive, proactive framework for energy facilities. By leveraging historical data, predictive analytics, and real-time monitoring, the model ensures that critical spares and maintenance materials are available when needed, maintenance activities are executed efficiently, and plant uptime is maximized. Digital integration and automated monitoring further enhance visibility, decision-making, and operational resilience, positioning the model as a strategic enabler of cost-effective, safe, and reliable energy facility operations (Pagoropoulos *et al*., 2017; Molina *et al*., 2017).

2.4 Risk Management and Resilience

Risk management and resilience are critical components of inventory availability and plant uptime optimization in energy facilities. These facilities operate in high-stakes environments where equipment failures, supply chain disruptions, and unplanned downtime can result in substantial financial losses, safety hazards, and operational inefficiencies. The complexity of energy systems, coupled with dependence on specialized equipment and materials, amplifies the consequences of poor risk management. A proactive approach that integrates inventory, maintenance, and operational strategies is essential for mitigating risks and enhancing resilience.

Stock-out risks occur when critical spare parts, consumables, or maintenance materials are unavailable at the time of need, potentially leading to unplanned downtime, production losses, or compromised safety. Effective mitigation begins with accurate demand forecasting and inventory planning. By analyzing historical consumption data, failure rates, and maintenance schedules, energy facilities can determine appropriate stock levels for critical components. Safety stock and buffer strategies are essential to absorb variability in usage or lead times, especially for items with long procurement cycles or limited supplier availability. Inventory segmentation based on criticality allows prioritization of resources, ensuring that high-impact components are maintained at higher availability levels (Brown, 2017; Castellano *et al*., 2017). Additionally, monitoring inventory levels through digital dashboards and automated alerts enables timely replenishment, reducing the likelihood of stock-outs.

Supply chain disruptions pose significant threats to uptime and operational continuity. These disruptions may result from supplier failures, transportation delays, geopolitical events, natural disasters, or regulatory constraints. Contingency planning is a key resilience strategy, ensuring that energy facilities can maintain operations despite external shocks. Plans may include prequalified alternative suppliers, safety stocks of long-lead-time items, and prioritization of procurement for critical operations. Scenario analysis and stress testing are valuable tools for assessing potential vulnerabilities and developing response strategies. By simulating disruptions and evaluating recovery pathways, facilities can identify critical dependencies and implement mitigation measures proactively. Effective contingency planning reduces response time, minimizes operational impact, and strengthens organizational preparedness.

Redundancy and alternative sourcing are essential for enhancing resilience in the face of supply chain uncertainties. Redundancy involves maintaining multiple sources of critical components, either through additional inventory, duplicate suppliers, or regional stockpiles. Alternative sourcing strategies diversify supplier bases, reducing reliance on single vendors for essential items. In high-criticality scenarios, strategic partnerships and framework agreements with multiple suppliers ensure timely availability of components and services. Dual sourcing and vendor qualification programs not only mitigate the risk of disruption but also provide leverage in pricing negotiations and quality assurance. Redundancy strategies can extend to critical systems themselves, such as backup equipment or parallel operational capabilities, further enhancing uptime reliability (Colman-Meixner *et al.*, 2016; Nowell *et al.*, 2017).

Integrated risk management frameworks combine stock-out mitigation, contingency planning, and redundancy strategies to create a comprehensive approach to operational resilience. Digital integration, including ERP systems and predictive analytics, supports risk management by providing real-time visibility into inventory levels, supplier performance, and equipment condition. Data-driven insights enable proactive decision-making, early detection of potential disruptions, and optimization of risk response measures.

Risk management and resilience are fundamental to maintaining inventory availability and plant uptime in energy facilities. Mitigating stock-out risks, developing contingency plans for supply chain disruptions, and implementing redundancy and alternative sourcing strategies collectively enhance operational continuity, safety, and financial performance. A proactive, integrated approach ensures that energy facilities can withstand uncertainties, minimize downtime, and maintain high levels of operational reliability, positioning risk management as a strategic enabler of sustainable facility performance.

2.5 Performance Measurement and Continuous Improvement

Performance measurement and continuous improvement are critical components in optimizing inventory availability and plant uptime in energy facilities. These processes provide the mechanisms to evaluate operational effectiveness, identify inefficiencies, and implement corrective actions, ensuring that facilities maintain high reliability, safety, and cost efficiency. Given the complexity and capital intensity of energy operations, systematic performance measurement supports evidence-based decision-making and enhances strategic planning (Dolan *et al.*, 2016; Finnerty *et al.*, 2017). By integrating key performance indicators (KPIs), benchmarking, and feedback loops, organizations can drive operational excellence, improve resource utilization, and strengthen resilience against unplanned downtime.

The foundation of performance measurement lies in the identification and monitoring of Key Performance Indicators (KPIs) that reflect both inventory management and plant uptime objectives. One of the most critical indicators is Mean Time Between Failures (MTBF), which measures the average operational duration of equipment before a failure occurs. MTBF provides insight into the reliability of critical assets, helps prioritize maintenance interventions, and informs inventory planning for spares. By tracking MTBF, facilities can identify recurring failure patterns and implement preventive or predictive maintenance strategies to minimize downtime.

Stock-out frequency is another essential KPI, representing the number of instances when critical components or consumables are unavailable when needed. High stock-out frequency indicates inefficiencies in inventory management, potentially leading to production delays, increased emergency procurement costs, and compromised safety. Monitoring this KPI allows organizations to adjust reorder points, safety stock levels, and supplier engagement strategies to ensure availability of essential items.

Equipment availability, expressed as the proportion of time that systems or assets are fully operational, is a direct measure of operational performance. High equipment availability signifies effective maintenance scheduling, optimized inventory support, and minimal operational disruptions (Paul *et al*., 2016; Erkoyuncu *et al*., 2017). These KPIs, collectively, provide a comprehensive view of the efficiency and reliability of inventory and maintenance processes, enabling data-driven decision-making and performance evaluation.

Benchmarking provides a comparative perspective that enhances performance measurement by identifying gaps and opportunities for improvement. By comparing MTBF, stock-out rates, and equipment availability against industry standards or peer organizations, energy facilities can evaluate their operational efficiency relative to best-in-class practices. Benchmarking also informs strategic decision-making, helping facilities adopt proven methodologies, technologies, and process improvements that have been successful in similar operational contexts (Ketter *et al*., 2016; Wibowo and Grandhi, 2017). Furthermore, benchmarking facilitates target-setting, providing realistic and aspirational performance goals based on validated industry experience.

Continuous improvement is enabled by establishing structured feedback loops that link performance measurement outcomes to operational and strategic interventions. Data collected from KPIs and benchmarking exercises is systematically analyzed to identify root causes of underperformance, recurring failures, or inefficiencies in inventory and maintenance processes. Feedback is communicated to relevant stakeholders, including procurement, maintenance, operations, and management teams, to inform corrective action plans. Iterative improvement cycles ensure that lessons learned from past performance are integrated into updated operational practices, maintenance schedules, and inventory management strategies.

Advanced digital tools further enhance continuous improvement processes by providing real-time data visualization, predictive analytics, and automated reporting. Enterprise Resource Planning (ERP) and Computerized Maintenance Management Systems (CMMS) enable dynamic monitoring of inventory levels, asset health, and maintenance interventions, facilitating rapid adjustments to procurement, stock replenishment, or maintenance scheduling. Predictive insights from these systems allow organizations to preempt failures, reduce unplanned downtime, and optimize resource allocation (Jin *et al*., 2016; Alam *et al*., 2017).

The integration of KPIs, benchmarking, and feedback loops creates a culture of accountability and continuous learning within energy facilities. Employees at all levels become engaged in identifying improvement opportunities, monitoring outcomes, and implementing innovative solutions. Continuous improvement also supports strategic alignment, ensuring that inventory and uptime management efforts contribute to broader organizational objectives such as cost efficiency, operational resilience, safety compliance, and sustainability.

Performance measurement and continuous improvement are essential for enhancing inventory availability and plant uptime in energy facilities. By monitoring KPIs such as MTBF, stock-out frequency, and equipment availability, benchmarking against industry best practices, and implementing feedback loops for iterative improvement, organizations can optimize operational efficiency, reduce unplanned downtime, and strengthen resilience. A structured, data-driven approach ensures that inventory and maintenance processes are continuously refined, transforming operational management into a proactive, value-creating function that supports sustainable performance and long-term reliability in complex energy operations.

2.6 Expected Outcomes and Strategic Benefits

The implementation of a structured model for inventory availability and plant uptime improvement in energy facilities offers significant operational, financial, and strategic benefits. Energy facilities are capital-intensive and technologically complex systems, where unplanned downtime, equipment failures, and supply chain disruptions can have cascading consequences on productivity, safety, and costs. By integrating demand forecasting, inventory optimization, maintenance scheduling, and digital monitoring, organizations can achieve improved operational reliability, enhanced cost efficiency, and strengthened resilience (Chase, 2016; Lv and Lin, 2017). The expected outcomes of such a model span plant performance, financial savings, safety compliance, and supply chain effectiveness.

One of the primary outcomes of the model is the improvement of plant uptime and operational continuity. High uptime ensures that energy facilities operate consistently at their designed capacity, delivering uninterrupted energy supply and meeting production targets. By aligning inventory management with preventive and predictive maintenance schedules, the model ensures that critical components and spares are available when required, reducing the likelihood of maintenance delays or extended equipment downtime. Predictive analytics and real-time monitoring further enhance uptime by identifying potential equipment failures before they occur, enabling timely interventions. Operational continuity not only supports production efficiency but also reinforces stakeholder confidence, mitigates revenue losses, and reduces the risk of cascading system failures that can compromise other interconnected processes.

A strategic benefit of improved inventory availability and proactive maintenance planning is the reduction of costs associated with unplanned downtime and emergency procurement. Unplanned outages often necessitate rapid procurement of critical components at premium prices, expedited shipping, and additional labor costs, all of which inflate operational expenditure. By maintaining optimal stock levels of critical and high-impact items, energy facilities minimize the need for emergency interventions, achieving both direct cost savings and indirect financial benefits through uninterrupted production. Additionally, coordinated maintenance and inventory planning reduce resource wastage and optimize procurement cycles, contributing to more predictable budgeting and improved capital allocation across the organization (Madanhire and Mbohwa, 2016; Fang *et al.*, 2016).

Operational reliability and safety are intrinsically linked to inventory availability and maintenance efficiency. Ensuring that critical spares and maintenance resources are readily available reduces the risk of equipment malfunctions that could lead to hazardous incidents. High plant uptime and well-maintained assets enhance the reliability of energy delivery and mitigate operational hazards to personnel and the environment. Moreover, energy facilities are subject to stringent regulatory frameworks governing safety, environmental compliance, and operational standards. The model supports adherence to these requirements by systematically integrating preventive and predictive maintenance, equipment monitoring, and inventory planning. Maintaining compliance reduces the risk of regulatory penalties, reputational damage, and legal liabilities while promoting a culture of operational excellence and corporate responsibility (Parella, 2017; Armour *et al.*, 2017).

The model also delivers strategic benefits through strengthened supply chain performance and optimized resource utilization. By segmenting inventory into critical, strategic, and routine items, organizations can prioritize resource allocation and engage suppliers effectively. Long-term supplier partnerships, redundancy strategies, and alternative sourcing options enhance supply chain resilience, ensuring the continuous availability of components even in the event of disruptions. Digital integration through Enterprise Resource Planning (ERP) and real-time monitoring systems further supports visibility across procurement and maintenance processes, enabling data-driven decision-making and more efficient use of resources. Optimized storage, replenishment strategies, and inventory turnover contribute to reduced holding costs and better utilization of capital while ensuring operational reliability.

Collectively, these outcomes translate into broader strategic advantages for energy facilities. By achieving higher uptime, cost efficiency, regulatory compliance, and supply chain robustness, organizations can strengthen their competitive position, enhance stakeholder confidence, and support sustainable growth. The model transforms inventory and maintenance management from a reactive, transactional activity into a proactive, value-creating function that directly contributes to operational resilience and organizational performance. Enhanced operational reliability also allows facilities to respond more effectively to market fluctuations, regulatory changes, and technological advancements, ensuring long-term adaptability and sustainability (Kamalahmadi and Mellat-Parast, 2016; Wang *et al*., 2017).

The adoption of a structured model for inventory availability and plant uptime improvement generates tangible operational, financial, and strategic benefits. Improved plant uptime ensures operational continuity, while reduced costs from unplanned downtime and emergency procurement enhance financial efficiency. Safety, reliability, and regulatory compliance are reinforced, and the supply chain becomes more resilient and efficient. By integrating predictive analytics, inventory optimization, maintenance planning, and digital monitoring, energy facilities can achieve sustained performance improvements, positioning strategic inventory and uptime management as a critical enabler of long-term operational success and resilience.

CONCLUSION

The model for inventory availability and plant uptime improvement demonstrates significant strategic relevance for energy facilities by directly addressing the challenges of operational continuity, equipment reliability, and cost efficiency. Energy operations are inherently complex, capital-intensive, and highly dependent on the availability of critical spares and maintenance resources. The proposed model provides a structured and systematic framework that integrates demand forecasting, inventory segmentation, maintenance planning, and digital monitoring to ensure that essential components and services are available when needed. By aligning inventory management with preventive and predictive maintenance schedules, the model enhances operational reliability, minimizes unplanned downtime, and supports the strategic objectives of efficiency, safety, and sustainability.

A key strength of the model lies in its emphasis on integrated, proactive inventory and maintenance management. Unlike traditional reactive approaches, which respond to equipment failures or stock-outs after they occur, the model leverages data-driven decision-making, predictive analytics, and real-time monitoring to anticipate potential disruptions and optimize resource allocation. Segmentation of inventory based on criticality, alignment with maintenance schedules, and integration with digital systems enable organizations to prioritize resources effectively, reduce emergency procurement costs, and maintain high plant uptime. This proactive orientation not only strengthens operational performance but also reinforces safety standards, regulatory compliance, and overall resilience of energy facilities.

Given the dynamic and rapidly evolving nature of energy operations, characterized by technological innovation, fluctuating demand, and supply chain uncertainties, continuous evaluation and adaptation are essential. Performance measurement through key indicators such as equipment availability, stock-out frequency, and Mean Time Between Failures (MTBF), combined with benchmarking and iterative feedback loops, allows organizations to refine inventory and maintenance strategies over time. Adopting a culture of continuous improvement ensures that the model remains responsive to emerging challenges, enhances decision-making, and sustains operational excellence.

The integrated model for inventory availability and plant uptime provides a strategic, proactive, and adaptive approach to managing critical energy facility operations. By combining inventory optimization, predictive maintenance, and digital monitoring, the model enables energy organizations to achieve operational reliability, cost efficiency, safety, and resilience, establishing inventory and maintenance management as a core value-creating function.

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