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Identifying Required Data for Power Generation O&M Investment Plan Decision Making

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Throughout the lifecycle of a power plant, utility companies must decide the implementation of operation and maintenance (O&M) through investment planning. Additionally, the data available to support the investment plan decision in terms of O&M management are affected by a number of variables. This paper provides an innovative approach to identify possible data and decision-making approaches in O&M investment planning in a power generation company. It takes a case study of PT PLN (Persero), also known as PLN, the electricity provider in Indonesia that focuses on the power generation sector and constantly involves decision-making for power plant O&M through investment planning. Throughout the course of the study, seven additional decision-making factors, namely, urgency, alternative study, technical feasibility, financial feasibility, land, environmental and social, legal, and Governance, Risk, and Compliance (GRC), are uncovered in the existing investment planning model. It has been determined that these aspects could be backed by data derived from best practices or those already present in the PLN. Furthermore, this paper also recommends potential future improvements that can be implemented in the power generation O&M management investment planning. As a future improvement, a more structured decision-making process, such as the SALVO process, should be implemented to support the effort to create a robust and transparent decision-making process to realize continuous asset value growth.

Keywords: data, decision making, investment plan, lifecycle, O&M, power generation.

1. Introduction

Data are critical components of the rapidly evolving society's information technology (IT) in many different sectors, including the power generation sector. The components' dependability, availability, and maintenance of power generation assets demand extra attention due to the complexity of the data and equipment used in the power generation as such. In order to make decisions regarding optimal maintenance and the timing of asset renewal, replacement, or decommissioning, it is necessary to track maintenance data and information, including its impact on expenses. Data collecting and enhancing technologies used in O&M practice are required to complement the O&M optimization in asset management.

Various evaluations of industrial communication and data management systems have detailed the vast volume of data created by production automation and sophisticated equipment and sensors. Particularly, predictive maintenance is gaining importance for cost reduction and business performance improvement (Jimenez Cortadi et al., 2019). Predictive maintenance (PM) uses a variety of data sources to detect anomalous equipment behavior (diagnosis), anticipate future failure mechanisms (prognosis), and enable proactive decision-making (proactive decision-making) (Do et al., 2015). Through direct operator supervision and online monitoring of all performance metrics (including losses), digital computer-based automated control systems have made it feasible to provide nearly non-stop performance control (Mao & Xiao, 2018). Moreover, from the asset management perspective, as stated in ISO 55001, an organization shall specify, implement and maintain processes for managing its information, where data obviously is one of the key components in information management. The organization should ensure the deliverable of good quality data and information, which has to be supported by well-maintained data management. In recent years, the use of big data has become a trend in many businesses, and inevitably in the future, such a thing will become a necessity, especially in the power generation industry.

As a result of the power generation industry's complex assets, the demand for data-driven technologies and the quality of its products will expand. Consequently, evaluations pertaining to data composition and quality in the power generation industry, in this case PLN, are crucial to overcoming obstacles in digital transformation and establishing a competitive advantage through the O&M investment plan decision-making procedure. This approach then determines the optimal approach in O&M management by analyzing and comparing the O&M management practices of other organizations with similar business processes to PLN. The authors subsequently evaluated how these data affect PLN's O&M investment strategy. The objective is to discover the data and information enhancements that could aid O&M investment decisions.

2. Literature Review

Initially, review articles on the topic of O&M management systems, in general, were explored in this study. The goal was to discover prior similar studies published that explored this topic in general or for specific applications or systems. The authors also examined, categorized, and assessed the approaches used in the related papers. Based on the review, a few articles have been published to date that have focused on various models and approaches to data utilization in O&M decision-making process.

Maintenance has a broader viewpoint in today's industries (Simões et al., 2011). Referring to the paper from Simões et al. in 2011, maintenance has traditionally been crucial to businesses due to its diverse operations, resources, measurement, and management. However, the necessity to handle the many aspects of maintenance more efficiently has grown in recent years as a result of changing operating technology and the changing organizational function of maintenance.

Maintenance was considered an inevitable expenditure until around 1940, and the only maintenance available was CM (Corrective Maintenance), while it is advisable to use qualitative and quantitative aspects of reliability which is related to mathematical and statistical concepts in reliability modeling (Blischke & Murthy, 2000). Interpreting data in order to maintain equipment as efficiently as feasible is one aspect of maintenance management. To accomplish such, a large amount of data must be obtained and analyzed; valuable data comes from sensors, customers, maintenance- and operational people, economic departments, environmental concerns, laws and regulations, and many more.

Regarding O&M management in power generation, a 2009 World Bank report on O&M management in India reveals that power plants run by state-sector utilities have major shortcomings; in other cases, the IT infrastructure inside the plant is virtually nonexistent. Longer-term solutions might include purchasing a Computerized Maintenance Management System (CMMS) and building a decision-making system that links maintenance expenditures to station dependability. Establishing an in-house Budget Committee and preparing a comprehensive budget manual, as well as performing training for utility workers to function under a performance-based budget regime, will boost the generation budgeting process. In the field of Generation Planning, a gradual transition from the 'Bottom Up' strategy (based on what is easily feasible) to the 'Top Down' approach is required (based on the desired level of performance) (The World Bank, 2009).

Abadi et al. (2020) have classified the main studies in O&M management and used surveys to describe their findings and to represent future research opportunities in this field. Their study revealed the most frequently used terms in articles on O&M management in the Engineering Village – Elsevier database. The search has been refined down to particular criteria such as maintenance, decision making, dependability, and scheduling to restrict the results. The result depicts more than 50 essential keywords describing the subjects and methodology of these articles. These keywords can be used to demonstrate the main issues and trends in the subject of O&M management.

3. Investment Plan Decision-Making in PLN

The sheer number of options to consider and the volume of decisions that must be taken on a regular basis, especially in large companies, makes implementing an effective decision-making process a critical component of running a successful business. Thus, data and decision-making could not be separated. In the power generation cycle in PLN, regardless the fuel type of the power plant, the most critical and strategic decisions are made during the project investment planning phase. The project investment planning phase also covers the “go or no-go” of budget approval during the overhaul and periodic maintenance of power plant units. The internal rule of the PLN specifies that the power plant unit manager is the one who is responsible for submitting the budget proposal to the supervising directorates. A verification procedure is carried out by the Verification and Validation Team (VVT) prior to the decision being taken by the investment planning committee, which is comprised of the board of directors and the top management of the company.

The investment program is divided into four categories; infrastructure projects, maintenance CAPEX, distributions, and non-infrastructure projects. The obligatoriness of the project depends on the program objective itself, also taking into account external factors; for instance, there are high legal risk implications if the project is not executed. Also, if the government mandates the project, the project should be executed to avoid sanction from the government. Then, as soon as the obligatoriness of the project has been verified, the economic aspect would be assessed. It is identified by the Internal Rate of Return (IRR), which should be higher than the Weighted Average Cost of Capital (WACC).

The existing flow of decision-making and the criteria that are being used may not be ideal, given the complexity of the projects being worked on by PLN. Specifically, concerning the O&M investment plan, where financial and technical aspects must be examined thoroughly to deliver accurate asset economical and performance for the information inputs during the decision-making process.

4. Benchmarking O&M Data Requirements

The initial phase of the approach is to determine the significance of the data. It is conducted by analyzing different O&M investment strategies from multiple sources, primarily power production sectors. The authors generalized the principles from various power generation resources. The best practice data requirement as a result of benchmarking review is indicated on Figure 1.

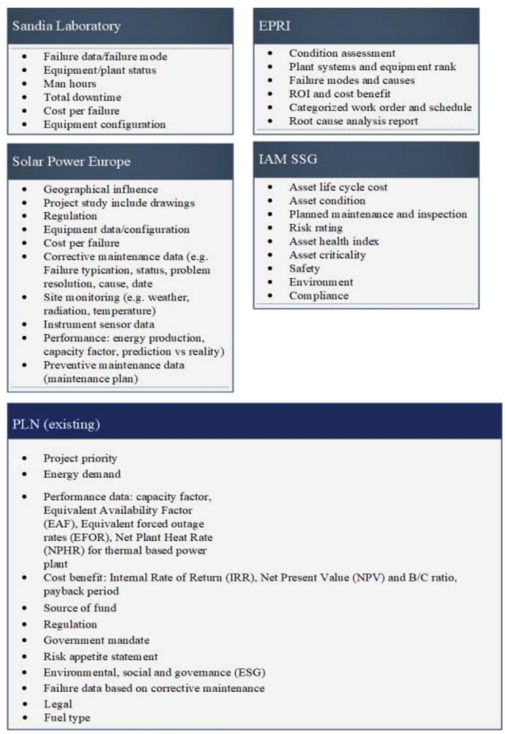

Fig. 1. Data requirement benchmarking result

Guidelines reviewed in this study are derived from the Sandia Laboratory report, which focuses on wind energy O&M practice, Operation & Maintenance Best Practices Guidelines released by

SolarPower Europe, Subject Specific Guidance from the Institute of Asset Management, and EPRI guidance for maintenance planning and scheduling. Figure 1 demonstrates that PLN's current data collection lacks a number of investment plan decision-making data requirements. Upon closer inspection, the majority of PLN's unpresentable data relates to statistical parameters, reliability, and predictive maintenance. Even though best practices state that predictive maintenance and reliability analysis can detect equipment problems before they fail, reduce downtime, and increase asset dependability, performance, and safety, PLN does not currently have the necessary data to optimize and extend the lifecycle of its power plants. These data are extremely useful for statistically forecasting maintenance within power plant units, analyzing the pattern of outages, and analyzing the reliability of O&M operations.

5. The Relation Between Data and Decision-Making Aspects

5.1.*Decision criteria of PLN's O&M investment plan*

The next stage is to identify the decision criteria that are used in the O&M investment plan. In this research, the authors examine a variety of VVT verification reports. The result reveals that several crucial aspects have not been discussed explicitly in the internal regulation decision-making workflow. The aspects are the following:

(i) Urgency
The urgency of the project describes the project's core objective and demonstrates the impact severity that could occur if the project fails to be executed. Hence the O&M project executor should indicate its criticality.

(ii) Alternative study
This aspect shows possible alternatives to the proposed investment project, it includes scenarios if later the project is not approved.

(iii) Technical and operational feasibility
The technical and operational feasibility aspect requires analyses of O&M data of the power plant. These analyses must show the current condition of the power plant and the possible impact of the project on the operational performance of the power plant (whether it would increase or decrease the performance).

(iv) Financial feasibility
In order to be able to ensure that the proposed project is profitable, the budget proposal should include the financial calculation. The calculation would indicate the project's budget and economic parameters to determine economic and financial viability.

(v) Legal aspect
It is important to identify and discuss any legal concerns or ramifications that may arise in connection with the project.

(vi) Land, environmental and social aspects
The level of environmental and social effect reduction is one of the project prioritizing criteria in PLN, hence environmental and social assessments are essential. Land disputes, which are typical in large-scale power plant projects, must be avoided because they might impede project implementation.

(vii) Governance, Risk, and Compliance (GRC)
The aspect includes the result of risk assessment, Fraud Risk Assessment (FRA), Conflict of Interest assessment, and Confidentiality, integrity, and availability (CIA) analysis.

5.2.*Categorizing data requirements into decision-making aspects*

Hahn et al. (2017) presented a method for providing data groups for O&M practice by stating the objectives and analysis employed for each data group. Referring to this, as part of the data grouping assessment in the approach, the authors then categorized the combined data requirements in accordance with the seven dimensions of decision-making, as indicated in Table 1. To support the precision and consistency of decision-making criteria, it is determined that a proper data collection system must be established.

Table 1. Data grouping based on decision-making aspect

Aspects	Possible objectives	Possible methods	Data group
Urgency	Identify asset criticality Monitor Asset Health index Executing government mandate Executing renewable energy transition project	Composite metric	Asset condition Equipment/plant status Plant systems and equipment rank Geographical influence Equipment configuration Failure data/failure mode Condition assessment Project priority Energy demand Performance data Source of fund Fuel type
Alternative study	Design optimization Maintenance optimization Degradation monitoring	Degradation models Advanced physical models (e.g. modelling fluid structure interaction) Maintenance and logistics optimization Data mining Vibration analysis Optimized renewal	Equipment/plant status Total downtime Equipment configuration Geographical influence Project study include drawings Instrument sensor data Maintenance plan Corrective maintenance data
Technical and Operational	Performance Reliability Availability Maintainability Root cause analysis	Fault-Tree-Analysis, Failure mode event analysis (FMEA) Pareto-Analysis Basic physical models (e.g. Miner's rule) Statistical calculations (e.g. average values) Stochastic simulation Simple plots (such as histograms) Vibration analysis Reliability block diagram	Failure data/failure mode Equipment/plant status Total downtime Equipment configuration Project study include drawings Condition assessment report Categorized work order and schedule Root cause analysis report Site monitoring Instrument sensor data Performance data Energy demand
Financial	Calculate Life cycle cost Calculate cost-benefit Calculate O&M cost	Stochastic simulation Cost-Benefit analysis	Cost per failure Cost benefit Source of fund Return of Investment Asset life cycle cost Man hours

It can be stated that more thorough data inputs could improve the investment decision that would be made. The investment committee relies on data to make defensible decisions and generate meaningful business outcomes. Grouping data into decision-making aspects could enable the integrated data flow to meet the need for supporting information during the decision-making procedure. This data grouping indicates that certain data are necessary for more than one aspect. For instance, geographical influence appears on urgency, alternative study, land, environmental and social, and GRC. Geographical influence plays a role in determining the urgency as it influences the stage of the power generation system on the grid, and corresponds to the geographical electricity demand. The geographical characteristic obviously correlates to land availability and environmental and social condition. In terms of GRC, geographical influence must be taken into account as it could increase risk and hazard used in the risk assessment, e.g., disaster risk.

Similar logic also applies to other data groups, e.g., failure mode, site monitoring, and so forth. Statistical, stochastic, and reliability analyses are also found to be closely related to the techniques employed for technical and financial elements. As these methods involve time series analysis, the input data groups should be recorded over an extended period of time. As historical data are vital, high data quality must be provided to guarantee the precision of the statistical computation or forecasting by means of stochastic simulation. Therefore, PLN should develop a "single source of truth" for data and determine the criteria for data governance in order to preserve the data and information life cycle. In the future, PLN should deploy digital analytics solutions that transform how power-generating firms obtain, consume, and learn from their data based on Table 1's data requirements. This solution would assist PLN in realizing data potential for cost reduction, efficiency enhancement, and risk management.

5.3. Decision criteria of PLN's O&M investment plan

The process of enhancing the decision-making process through data has to be complemented by the determination of each data group's relation across different decision-making aspects. The authors analyzed it using a causal loop diagram.

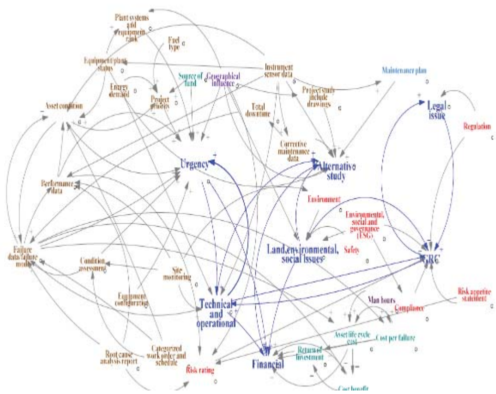

Fig. 2. Causal loop diagram of data interdependency

This causal loop diagram indicates that multiple data groups are interrelated. It can be used as a reference or initial framework in developing data. Thus, the completeness and availability of the data influence other data groups. It is crucial for the company to identify data management roles and responsibilities in order to ensure the quality of decision-making data. The party assigned these responsibilities must evaluate the completeness, validity, and accuracy of the data. It is also essential to note that effective database management is required for the successful transmission of data from one data group to another. Maintaining the consistency of the asset register and the primary keys is one of the aspects that should be taken into account when administering the database.

5.4.Data prioritization and constrains

The authors also identify the prioritization level of each data group and identify constrains in obtaining good quality data according to use case in PLN. However due to confidentiality, the in-depth data of PLN use case’s investment decision could not be disclosed on this paper. The author set the priority level as high, medium and low. High priority means that the data is mandatory, thus lack of the data could influence the decision accuracy and effectiveness. Medium means the data is necessary, but the influence level is not as high as the high priority ones. Low priority means that this data is only influence the decision in specific cases. To complete the analysis, constraints found during investment plan decision-making in PLN use case are listed, as indicated in Table 2.

In the process of Operations and Maintenance (O&M) in power plants, it has been recognized that making effective investment decisions in dependable and modern equipment can play a crucial role in reducing operational and maintenance costs throughout the plant's lifespan. Evaluating the quality and durability of components, choosing reputable suppliers, and exploring the potential for automation and remote monitoring can enhance plant efficiency, minimize downtime, and optimize maintenance schedules. As a result, this can lead to cost savings and improved profitability. Furthermore, investing in high-efficiency power plant equipment and advanced technologies can have a positive impact on the plant's overall performance and output. Increased efficiency translates to lower fuel consumption, decreased operating expenses, and higher profitability. In general, investment choices made for a power plant can influence its economic performance, environmental sustainability, compliance with regulations, and ability to adapt to market fluctuations. It is essential to consider a wide range of factors when making informed decisions that align with long-term objectives and maximize returns while minimizing risks.

Table 1. Data prioritization and constraints

Decision-making aspect	Data type group	Priority	Constraints (in PLN's use case)
Urgency	Asset condition	High	The data sometimes does not represent the real condition
	Equipment/plant status	High	Equipment code is not standardized
	Plant systems and equipment rank	Medium	Complexity of data
	Geographical influence	Low	Lack of awareness from decision makers
	Equipment configuration	Medium	Validity and completeness of data
	Failure data/failure mode	High	Validity and completeness of data
	Condition assessment	High	Different method of condition assessment, therefore output may be varied
	Project priority	High	Project is mandated but unviable economically
	Energy demand	High	Validity and completeness of data
	Performance data	High	Validity and completeness of data
	Source of fund	Low	Currency fluctuation (when the source is from loan)
	Fuel type	Medium	Energy mix regulation that changes from time to time, that affects the project cost
Alternative study	Equipment/plant status	Medium	Equipment code is not standardized
	Total downtime	Medium	Validity and completeness of data
	Geographical influence	Medium	Lack of awareness from decision makers
	Project study include drawings	High	Unavailability of data or it is still in paper-based format
	Equipment configuration	Medium	Validity and completeness of data
	Instrument sensor data	High	Data consistency
	Maintenance plan	High	Validity and completeness of data
	Corrective maintenance data	High	Validity and completeness of data
Technical and Operational	Failure data/failure mode	High	Validity and completeness of data
	Equipment/plant status	High	Equipment code is not standardized
	Total downtime	High	Validity and completeness of data
	Equipment configuration	High	Validity and completeness of data
	Project study include drawings	Medium	Unavailability of data or it is still in paper-based format
	Condition assessment report	High	Different method of condition assessment, therefore output may be varied
	Categorized work order and schedu	High	Validity and completeness of data
	Root cause analysis report	High	Validity and completeness of data
	Site monitoring	Medium	Validity and completeness of data
	Instrument sensor data	High	Data consistency
	Performance data	High	Validity and completeness of data
	Energy demand	Low	Validity and completeness of data
Financial	Cost per failure	High	Validity and completeness of data
	Cost benefit	High	Validity and completeness of data
	Source of fund	Medium	Currency fluctuation (when the source is from loan)
	Return of Investment	High	Validity and completeness of data
	Asset life cycle cost	High	Data unavailability
	Man hours	Low	Validity and completeness of data
Legal	Regulation	High	Change of government policy
Land, environmental and Social	Environment	High	Lack of awareness from decision makers
	Geographical influence	High	Lack of awareness from decision makers
	Safety	High	Lack of awareness from decision makers
	Regulation	Medium	Change of government policy
	Site monitoring	Low	Validity and completeness of data
	Environmental, social and governan	Medium	Lack of awareness from decision makers
Governance, Risk and Compliance	Compliance	High	Lack of awareness from decision makers
	Regulation	High	Change of government policy
	Root cause analysis report	High	Validity and completeness of data
	Risk rating	High	Validity and completeness of data
	Risk appetite statement	High	Lack of awareness from decision makers
	Performance data	Medium	Validity and completeness of data
	Environmental, social and governan	Medium	Lack of awareness from decision makers
	Geographical influence	Low	Lack of awareness from decision makers

6. Conclusion

According to the research undertaken for this work, data-driven decision-making could imply reaching crucial organizational goals by utilizing verified, analyzed data. A solution is provided in this paper for enhancing the data requirements by adding data from best practices. Incorporating business-specific data and criteria with O&M management best practices would provide some insight for investment planning decision-makers, according to the findings of this study. Looking at PLN's use case, for instance, nonexistent data that are required to undertake crucial analyses, such as statistical and probability analyses, should be added if PLN wishes to sharpen the decision-making process's outcome. These components might support the cost, risk, and performance forecast, which is advantageous for enhancing investment planning selections.

In conclusion, it has been determined that the importance of accurate data collection and analysis for optimizing both O&M management and cost is extremely advantageous for enhancing O&M management in the power generation business. The implementation of the preceding procedures in this study will raise the quality (accuracy, consistency, and integrity) of reliability data and, consequently, its worth to all power-generating O&M investment, development, operation, and insurance. Additionally, this type of research is applicable to other power generation businesses with comparable business processes. The identification of data requirements and their relation to decision-making would facilitate maintenance policies, methods, and practices that are safer, more effective, and more efficient. Failure to do so will hinder the rate at which probabilities improve operational and maintenance decision-making precision.

7. Future Improvement

In terms of the decision-making process improvement, PLN may adopt the SALVO process, a four-year cross-sector R&D collaboration project to support industries to assess and demonstrate the value of asset investments, maintenance, spares, change initiatives, or renewals (Woodhouse, 2015). The SALVO is a 6-step process that leads through the top-down stages of focusing on the correct problems to solve, identifying what can be done (including lateral thinking options that may not require technical intervention), and quantified cost/benefit/risk evaluation of the various options.

Fig. 4. SALVO Process

The first step is to identify and prioritize problems or opportunities in order to make the most significant use of asset health and criticality information, as well as to determine the best approach to combine assets for shared attention and management strategies. The second stage is defining the problem. The Root Cause Analysis (RCA) methodology can assist in understanding the interplay of components that must be addressed, and resolving these fundamental issues may also eliminate other difficulties. Step 3 of SALVO, identifies a potential solution that requires considering a wider variety of potential solutions, including design, procurement, operations, maintenance, renewal, and other mitigation methods. Step 4 is to evaluate and optimize the timing of discrete options by incorporating life cycle cost/benefit/risk, optimal intervals, and cost of uncertainty. Evaluating and optimizing combinations or interventions is step 5, which aims to reduce downtime, raise productivity and receive assurance from stakeholders. The last step is assembling the total program, including capital investment plans, resourcing needs, and risk and cost forecasts.

References

Blischke, W., & Murthy, D. (2000). *Reliability: Modeling, Prediction, and Optimization*. https://doi.org/10.1002/9781118150481

Do, P., Voisin, A., Levrat, E., & Iung, B. (2015). A proactive condition-based maintenance strategy with both perfect and imperfect maintenance actions. *Reliability Engineering & System Safety*, *133*, 22–32. https://doi.org/10.1016/j.ress.2014.08.011

Fadaeefath Abadi, M., Haghighat, F., & Nasiri, F. (2020). Data center maintenance:

Applications and future research directions. *Facilities*, *38*(9/10), 691–714. https://doi.org/10.1108/F-09-2019-0104

Hahn, B., Welte, T., Faulstich, S., Bangalore, P., Boussion, C., Harrison, K., Miguelanez-Martin, E., O'Connor, F., Pettersson, L., Soraghan, C., Stock-Williams, C., Sørensen, J. D., Bussel, G. van, & Vatn, J. (2017). Recommended practices for wind farm data collection and reliability assessment for O&M optimization. *Energy Procedia*, *137*, 358–365. https://doi.org/10.1016/j.egypro.2017.10.360

Jimenez Cortadi, A., Irigoien, I., Boto, F., Sierra, B., & Rodriguez, G. (2019). Predictive Maintenance on the Machining Process and Machine Tool. *Applied Sciences*, *10*, 224. https://doi.org/10.3390/app10010224

Mao, M., & Xiao, H. (2018). Study on key technologies of optimization of big data for thermal power plant performance. *AIP Conference Proceedings*, *1971*(1), 030015. https://doi.org/10.1063/1.5041134

Simões, J. M., Gomes, C. F., & Yasin, M. M. (2011). A literature review of maintenance performance measurement: A conceptual framework and directions for future research. *Journal of Quality in Maintenance Engineering*, *17*(2), 116–137. https://doi.org/10.1108/13552511111134565

The International Bank for Reconstruction and Development. (2009). *Strengthening Operations and Maintenance Practices In State-Sector Coal-Fired Power Generation Plants in India* (No. 53006). THE WORLD BANK GROUP. https://www.esmap.org/sites/default/files/esmap-files/P105191_53006_India_Strengthening%20Operations%20and%20Maintenance%20Practices%20In%20State-Sector%20Coal-Fired%20Power%20Generation%20Plants.pdf

Woodhouse, J. (2015). Extending SALVO decision-making disciplines into procurement, spares & inventory strategies. *Asset Management Conference 2015*, 1–4. https://doi.org/10.1049/cp.2015.1750